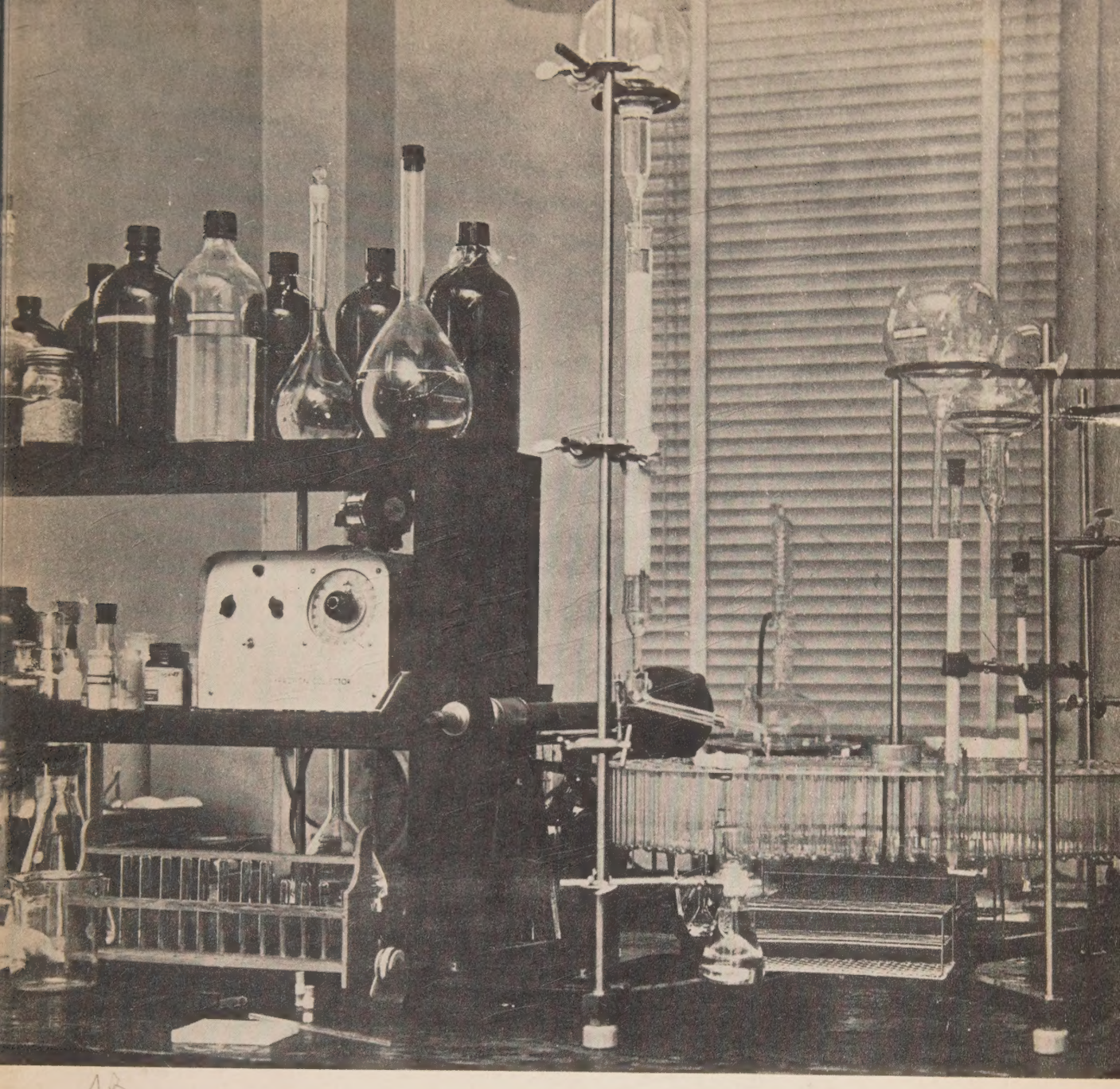

1958 REPORT

Experiment Station Committee

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

COMMONWEALTH MYCOLOGICAL INSTITUTE
4 - FEB 1959

THE COMMITTEE IN CHARGE

THE EXPERIMENT STATION

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

REPORT

October 1, 1957 to September 30, 1958

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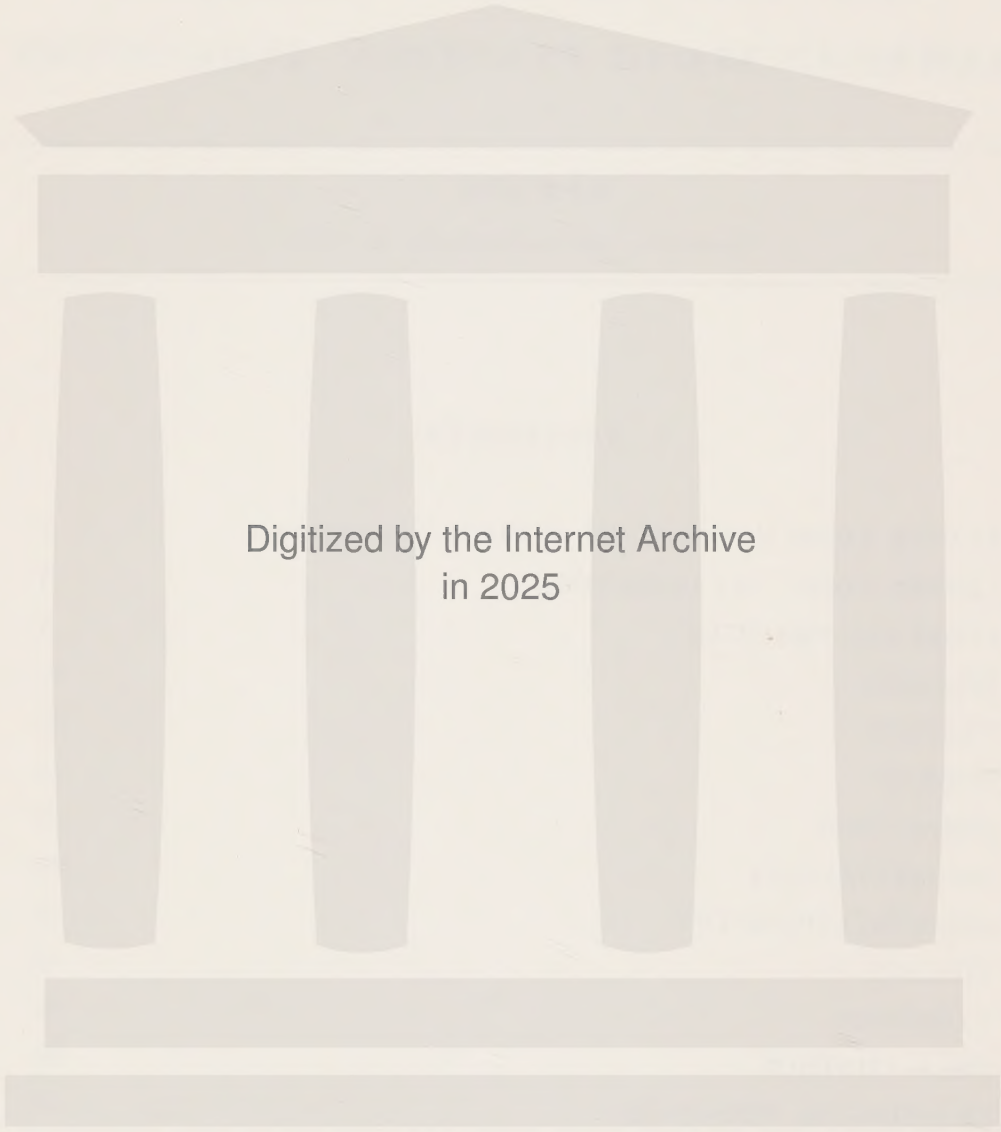
On the Cover:

Apparatus for chromatographic isolation of color substances in the sugar crystal.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HAWAIIAN SUGAR PLANTERS' ASSOCIATION

To The President and Members

Gentlemen:

The year 1958 has been a very difficult one for the entire sugar industry. The effects of the strike will be felt in varying degree by the 27 plantations for years ahead.

The Experiment Station has been and is doing its utmost to counter the immediate effects of the work stoppage. As for the longer term effects of higher costs, the Station staff continues as ever to seek new cane varieties, chemicals, operating methods, equipment and trained personnel to make it possible for the weaker units of the industry to survive and the balance to earn a reasonable profit.

We are proud of the accomplishments of our Director and the Station people in the past and have confidence that they will continue to contribute very materially to the health of the industry and, therefore, to the economy of the Territory in the trying years ahead.

Their reports for 1958 are herewith submitted.

Respectfully submitted,

EXPERIMENT STATION COMMITTEE

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R. A. Cooke, Jr.
H. B. Clark, Jr.
Chairman
F. A. Schaefer, III
H. A. Walker, Jr.

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W. M. Moragne
Karl Berg
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B. B. Alexander
R. G. Watt
F. E. Simpich, Jr.
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Secretary

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R. M. Frazier
A. E. Faye
John Cushnie
F. R. Wiley
L. D. Baver

To The Experiment Station Committee

Gentlemen:

This Experiment Station Report for the year ending September 30, 1958, is replete with many significant contributions to the Hawaiian sugar industry. Some outstanding strides have been made in many varied areas of the research program.

The strike of 1958 necessitated that the full resources of the Station be concentrated in assisting the plantations, both during and after the strike. Station personnel gave weekly talks to supervisors on the various aspects of sugar-cane research. Although some of these discussions may have been somewhat technical in spots to be thoroughly understood, the supervisors apparently were able to get a much clearer picture of the work of the Station staff. In addition, they obtained valuable information. Station personnel carried out experiments to obtain information on the germination of dry seed, on methods of evaluating the extent of damage to irrigated fields as an aid for deciding the sequence of harvesting fields, the spread of sour rot particularly as affected by irrigation, the reaction of seedlings to strike-imposed drought, and rat surveys.

The rat control program has been accentuated with special emphasis on determining the extent of the problem, especially on the island of Hawaii. New poisons are being studied with promising success. W. R. Smythe, a Station trainee, was added to the staff to concentrate on rat control.

The initial results from expanded nematode research have been so interesting as to warrant its continuance with unabated emphasis. Dr. Walter J. Apt, Associate Nematologist, USDA, is spending six months to continue the work started by Dr. Harold J. Jensen of Oregon State College. The Shell Chemical Company has given the Experiment Station a grant to expedite the nematode research program.

The Department of Sugar Technology, in cooperation with Kekaha Sugar Company, Ltd., the Silver Manufacturing Company, the Rietz Manufacturing Company and the Merrick Scale Manufacturing Company, is initiating basic and far-reaching research on cane diffusion. The diffusion equipment will be set up at Kekaha, and G. F. B. Appel, Jr., Assistant Technologist, has moved to Kauai to be in direct charge of the research.

Sugar quality research has made possible the identifying of the color-bearing substances in the sugar crystal. The inclusion of these colored substances within the crystal has been related to the rate of crystal growth.

The Field Engineering Department has designed and constructed a seed cane harvester which has undergone field trials at Kohala Sugar Company. The liliko problem, the highest cost item in present methods of cane harvesting, has been attacked by the development of a liliko machine that picks up unattached cane and a liliko cutter which handles attached cane. A moldboard plow has been designed and built to incorporate the basic principles of plow action resulting from soil studies by the Department of Agronomy. Teflon coatings have been found effective for increasing scouring and reducing draft.

Irrigation research has been expanded in all areas. The geophysicists and plant physiologists have been obtaining excellent results on evapotranspiration and water consumption in relation to climate. Dr. Jen-Hu Chang has joined the staff to concentrate on the climatological field. The soil physicists are studying water flow in furrows, water consumption of cane growing in lysimeters, moisture movement and the basic soil principles involved in infiltration as related to overhead irrigation. Dr. Frank E. Robinson has joined the staff to assist in this phase of the research. Dr. Robert D. Miller, Soil Physicist from Cornell University, spent his sabbatical leave with the Station and contributed many ideas to the expanding soil physics phase of the irrigation problem. The engineers are studying both surface and overhead irrigation in an attempt to obtain better mechanization of all field operations in addition to irrigation. E. M. Norum returned from his educational leave at the University of Minnesota to assist in the engineering phases of irrigation research.

The Experiment Station initiated research in Industrial Engineering with the appointment of Warren Gibson as Principal Industrial Engineer. The activities of the Industrial Engineer cut across all departments but are especially essential in aiding the Field Engineering program.

Research progress in Organic Chemistry has been highlighted by patent applications for the production of hardboards from bagasse using a new chemical which imparts both water and rot resistance to the board.

Dr. R. P. Humbert, Principal Agronomist, attended the International Potash Institute Congress in Madrid, Spain. His trip was sponsored by the Pacific Chemical and Fertilizer Company and the American Potash and Chemical Company.

During the year, 1358 new books and 73 new serials were added to the Station Library. The library now contains 69,500 items including catalogued material, government publications and project files. The botanical collection was increased by the acquisition of 35 books on ferns from the library of the late Dr. Harold L. Lyon. The entomological collection was increased by the purchase of 60 items from the library of E. C. Zimmerman. Mrs. John W. Waldron has donated to the Station Library the Hawaiiana collection of the late John W. Waldron, twice President of the HSPA. It consists of 300 books of great rarity and about 125 pamphlets.

Staff changes are listed on page 78.

Respectfully submitted,

EXPERIMENT STATION, HSPA

L D Baver

Director

CULTURAL PRACTICES

NITROGEN DISTRIBUTION SHOWS LITTLE EFFECT UPON YIELD AND JUICE QUALITY

New experiments at the Makiki Station have thrown considerable light on the utilization of nitrogen by sugar cane. The Makiki nitrogen test, harvested in June 1957, showed that large variations in the timing of nitrogen had little effect on yields. All of the nitrogen could be applied one month after planting and the yields equalled or exceeded those from plots receiving the nitrogen in small, delayed applications. There was evidence that 400 pounds of nitrogen per acre did not produce the full yield possible at Makiki.

Therefore, in the next trial, called Makiki N-K experiment, half of the plots received 600 pounds of nitrogen. The results show some gain in yield over the 400-pound level. Also, extreme variations in time of application of nitrogen resulted in rather small differences in yield and quality. Table 1 gives the yield and pol ratio from the inside lines. No statistical analyses of the data have been made, but it appears the following conclusions are justified:

1. Six hundred pounds of nitrogen per acre gave more sugar per acre than did 400 pounds of nitrogen per acre.

Table 1
Tons Pol Per Acre—1956–58 Makiki N–K Test. Inside Lines Only.

Plot No.	Pounds Fertilizer Per Acre		TPA	Pol Ratio
	1st Year	2nd Year		
1.....	400 NK	0	23.12	6.52
2.....	400 N	0	20.86	6.65
5.....	200 NK	200 NK	21.23	7.05
6.....	200 N	200 N	19.49	6.60
9.....	100 NK	300 NK	19.56	7.02
10.....	100 N	300 N	28.28	6.62
3.....	400 N	200 N	24.40	6.95
4.....	400 NK	200 NK	24.36	6.55
7.....	200 N	400 N	26.34	7.25
8.....	200 NK	400 NK	24.08	7.55
11.....	100 N	500 N	24.34	7.22
12*.....	100 NK	500 NK	16.49	7.98

*Plot 12 was a roadside plot. Heavy stalk damage contributed to the low yield.

2. The 400-pound plots, with all nitrogen on one month after planting, yielded as well as those receiving split applications.

3. As much as four-fifths of the total nitrogen can be applied on the thirteenth month without greatly reducing yield or quality.

In considering the implications of the third conclusion, it must be kept in mind that this cane is hand-harvested and the tops are discarded. The cane is kept greener by the very heavy late application of nitrogen and this would undoubtedly result in ill effects if machine-harvested. However, the good quality of the cane is even more surprising in view of the fact that there was no attempt to ripen by withholding water. Irrigation was continued until the week before harvest.

SPLITTING NITROGEN APPLICATIONS IN PLANT CROP SHOWS LITTLE EFFECT UPON NITROGEN COMPOSITION OF YOUNG RATOONS

Does late application of nitrogen result in better nutrition of the ratoon? Apparently, it makes little difference in either rate of growth of the young sprouts or in nitrogen content of the leaves. Table 2 shows that in those plots which received the entire 400 pounds of N two years before this sampling, the leaves contained about the same amount of nitrogen as was found in other plots. Leaves from the 600-pound plots had a nitrogen content slightly higher than those from the 400-pound plots, but the results were not entirely regular.

TAGGED NITROGEN (N^{15}) PRODUCES INTERESTING FACTS

A large volume of tagged nitrogen work was completed in the past year, coming from experiments which were begun two years ago.

In the first of these experiments, eight isolated stools of cane (37–1933) were fed tagged ammonium sulfate at the rate of 150 and 300 pounds of nitrogen per acre. The timing was varied in four ways as shown in Table 3.

The very interesting results of this experiment emphasize the value of N^{15} in nitrogen studies.

Table 2
Leaf Punches of Former N-K Plots
Harvested May 28, 1958
Ratoons 5 weeks old Sampled June 30, 1958
#3 leaves of larger plants were used.

		Fertilizer Schedule			
LPN	Av.	Before 9/1/56	3/7/57	7/10/57	Fert.
1. 1.89	1.88	400	—	—	N
2. 1.88		400	—	—	NK
5. 1.85	1.79	200	—	200	NK
6. 1.73		200	—	200	N
9. 2.02	1.92	100	—	300	NK
10. 1.82		100	—	300	N
3. 1.94	1.94	200	200	200	N
4. 1.95		200	200	200	NK
7. 1.84	1.89	100	100	400	N
8. 1.94		100	100	400	NK
11. 2.02	1.99	50	50	500	N
12. 1.96		50	50	500	NK

Average for all 600# N 1.94
Average for all 400# N 1.85

For example, leaf punch total nitrogen (LPN) did not show differences between the higher and lower rates of nitrogen fertilization, whereas the atom per cent excess N^{15} was in direct proportion to the amounts of fertilizer applied (Figure 1). Therefore, the higher levels of fertilizer were actually being used by the plants without LPN's giving any indication of the fact. In other words, the more readily available fertilizer nitrogen is being taken up in preference to soil nitrogen.

Figure 2 further illustrates the point. There is a smooth curve of increasing N^{15} content with increasing amounts of fertilizer without any very definite trend in LPN.

Table 3
Fertilization Schedule

Plot	1st application on 8/3/55	2nd application on 10/3/55	3rd application on 2/10/56	4th application on 6/1/56	Total
150–1.....	150	—	—	—	150
150–2.....	75	—	—	—	150
150–3.....	50	50	—	50	150
150–4.....	37.5	37.5	37.5	37.5	150
300–1.....	300	—	—	—	300
300–2.....	150	—	—	150	300
300–3.....	100	100	—	100	300
300–4.....	75	75	75	75	300

The prepared plots were planted in 37–1933 on May 25, 1955.

The amount of nitrogen left in the dead leaves as they are discarded by the cane plant is an excellent indicator of the richness of nitrogen supply, and is also a measure of the total nitrogen that has passed through the plant. Therefore, all leaf trash was collected and analyzed for estimates of monthly totals of N^{15} used. Figure 3 shows how the amounts of tagged fertilizer in the plant trash at different periods depend upon the timing of the applications. The four curves follow exactly the order to be expected.

When the trash nitrogen is plotted as cumulative amounts of nitrogen passing through the plants, it is found that early application is by far the most efficient in cycling the nitrogen (Figure 4). This probably offers some insight into the reason why it is very commonly found that the highest yields come from early nitrogen applications rather than from split applications.

In general, the sensitivity of trash total nitrogen appears to be greater than that of LPN.

For this experiment, average recovery of applied fertilizer nitrogen in the trash plus the harvested plants (above ground) was 29.10 per cent and 26.97 per cent for the 150 and 300 pounds nitrogen per acre, respectively. These values are in good agreement with findings for a similar test three years ago in which recovery was 26.0 per cent.

That much of the fertilizer nitrogen remains in the ground for future use is shown by the analyses of ratoons. The first ratoons were harvested after

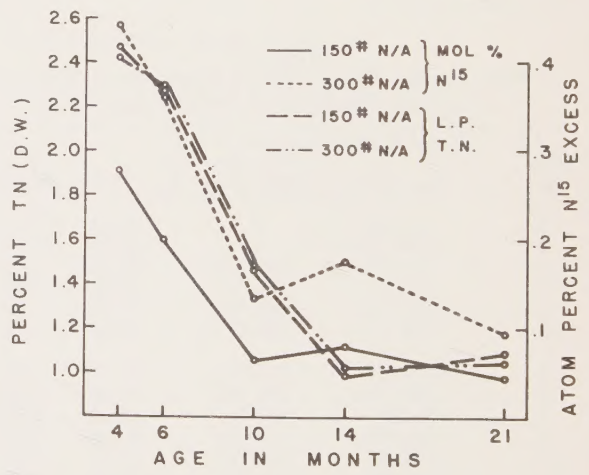

Figure 1. Relationship between age and nitrogen in leaf punches, expressed as total nitrogen and atom per cent excess N^{15} for two levels of N.

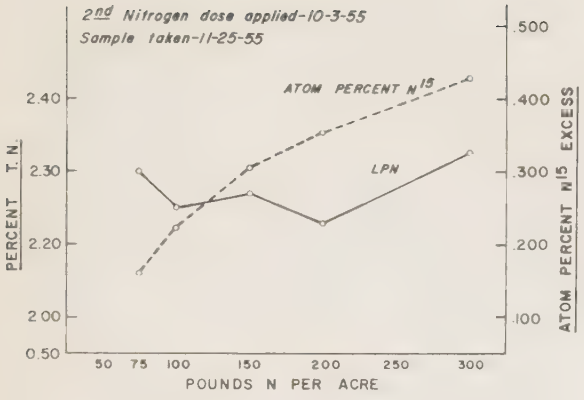

Figure 2. Comparison of atom per cent N^{15} nitrogen and per cent total nitrogen in leaf punches at six months of age.

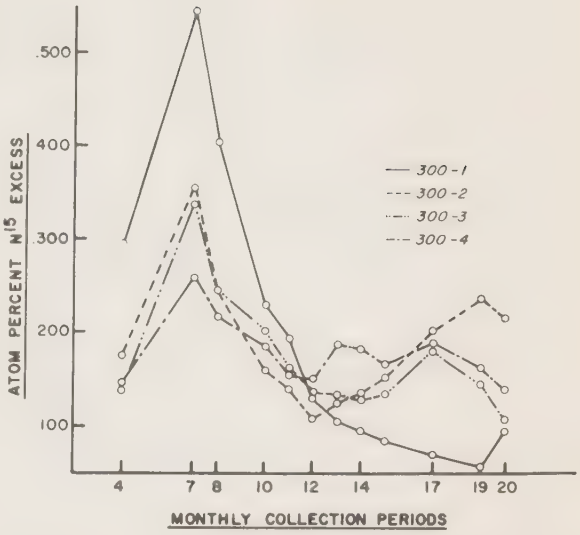

Figure 3. Atom per cent excess N^{15} concentration in trash collected periodically from 300 pounds N per acre.

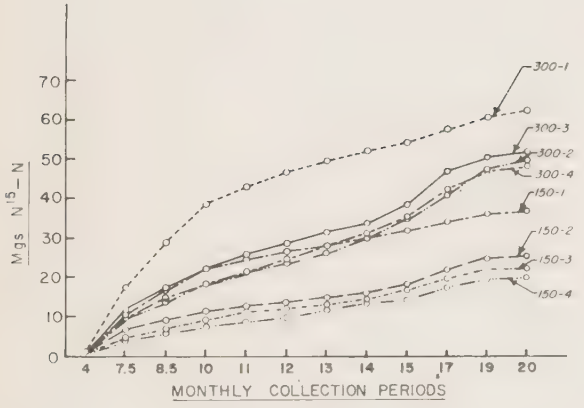

Figure 4. Cumulative losses of N^{15}-N in trash.

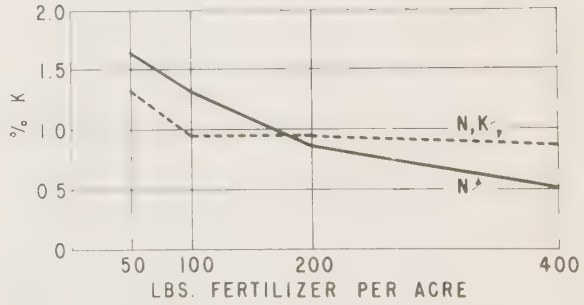

Figure 5. Potassium composition of 8-10 internode section at six months of age.

three and one-half months. The nitrogen in the crop was definitely labeled with N^{15}.

After the second ratoons had grown without added fertilizer until they were the size of well-fertilized plants six months of age, they were also harvested. Heavy nitrogen was found in all parts of these plants.

In both sets of ratoons, the highest labeling was in the plots which had received split applications. This was to be expected since the plant crop had used less fertilizer N than had the plots which received single applications.

NITROGEN IS ABSORBED BY FOLIAGE

The question has arisen as to whether ammonium sulfate can be absorbed by the cane tops. Table 4 shows that sulfate of ammonia is absorbed. It is absorbed much more slowly than urea when applied behind the sheaths.

Table 4

Time	Urea applied behind dewlaps	$(N^{15}H_4)_2SO_4$ applied behind dewlaps	$(N^{15}H_4)_2SO_4$ solution brushed on blades
	% absorbed	% absorbed	% absorbed
1 day.....	45.7	—	—
3 days.....	73.8	15.15	68.2
7 days.....	79.0	27.25	—

NITROGEN FERTILIZATION DEPRESSES POTASSIUM CONTENT OF PLANT

The depressing effect of nitrogen on potassium analysis of both sheath and stalk was again observed (Figure 5). With the higher levels of nitrogen, the tissue content of K falls below the values usually accepted as adequate for optimum growth. In this test, half the plots received K in amounts equal to the N. However, no increases in yields resulted from the added K. It will be necessary, therefore, to examine further the so-called critical levels of K when high levels of N are used.

In searching for the causes of K depression by nitrogen, total major bases (Ca, Mg, K) were measured in the cane tissues. It was found that as K decreased, Ca and Mg increased sufficiently to maintain a constant total base in milli-equivalents.

SHEATH AND STALK ANALYSES AGREE IN INDICATING POTASSIUM NEEDS OF PLANT

A total of 47 fertilizer experiments were logged in 1957 and 1958 to correlate plant composition with yield. The yield data from potash experiments indicate that the adequate levels for potassium in the sheath and 8–10 internode tissue are 2.20 per cent and .82 per cent, respectively. This is in agreement with the adequate levels originally set for these tissues.

Twenty-five potash experiments have been harvested from 1956 to 1958, in which both sheath and 8–10 internode samples have been collected. Both tissues were equally sensitive in indicating the potassium needs of the cane plant as reflected in cane and sugar yields.

TOTAL PHOSPHORUS IN INTERNODES 8–10 FORETELLS PHOSPHORUS NEEDS OF SUGAR CANE.

Yield data from previous and current crops in 23 field experiments on 10 plantations and two islands, phosphorus analyses of internodes 8–10, statistical studies, soil phosphorus and other pertinent data indicate:

1. Total phosphorus in internodes 8–10 determined in samples collected during a good growing season from plants aged approximately six to twelve months, may aid in determining the need for applications of phosphate in the field.

2. With phosphorus percentages below 0.032, yield gains from phosphate applications may be expected if the added phosphate is absorbed by the plant and if no other factor interferes. There is, in addition, some evidence of economic response with phosphorus percentages up to 0.040.

3. With phosphorus percentages ranging from 0.032 to 0.040 (or 0.045 depending upon the criterion used), phosphorus may be applied as insurance because yield gains are expected occasionally in this borderline range.

4. With phosphorus levels more than 0.038 to 0.046 (depending on the criterion used), yield gains are not expected and phosphorus applications are not needed.

PHOSPHORUS DEFICIENCIES RESTRICT STOOLING

In the most recent experiments, the plants were allowed to stool instead of being restricted to a single primary stalk in each culture jar. In the former experiments with single stalks, it was found that growth was restricted little or none by a

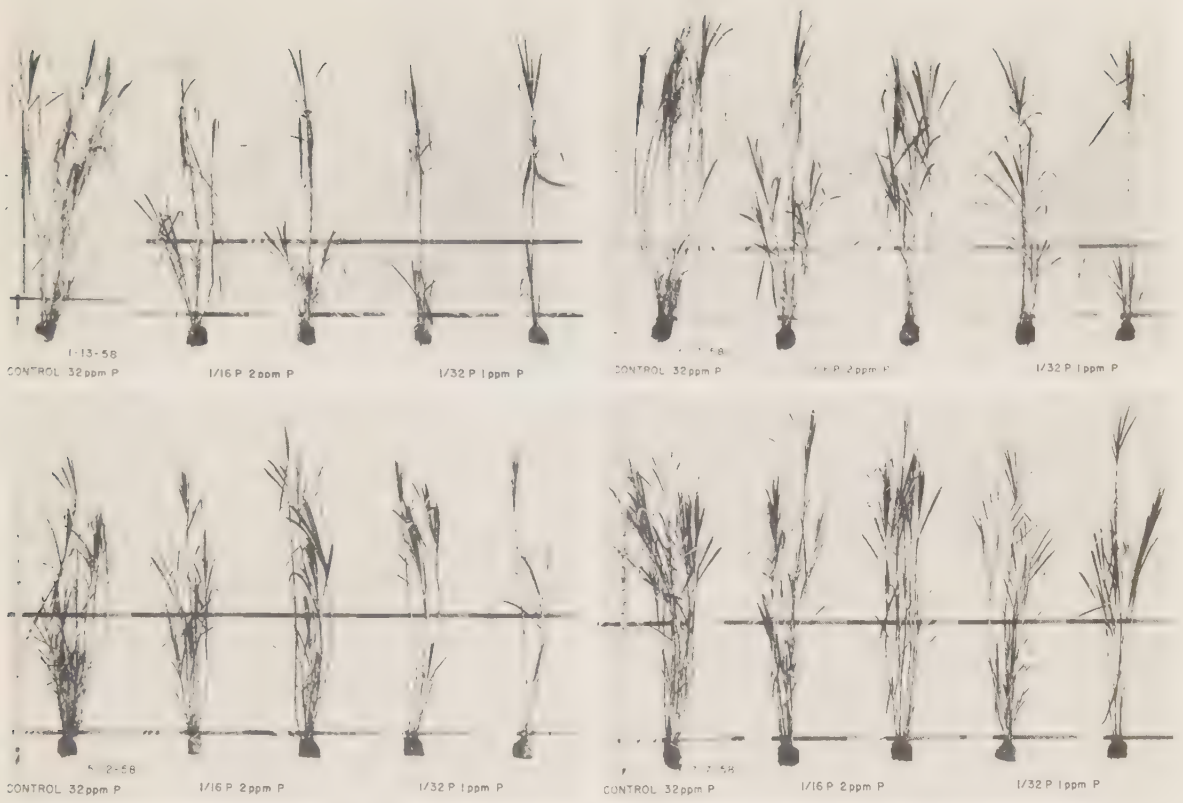

Figure 6. Variety 37-1933 was grown with three amounts of phosphorus and allowed to sucker. The cane was photographed and harvested at bi-monthly intervals: January, March, May and July, 1958.

phosphorus content of the tissues considered far below the critical level.

The major visible effect of P deficiency is upon stooling. The series of photographs in Figure 6, taken between the 13th of January and the 7th of July, 1958, illustrates the progress of stooling and growth of secondaries. The summary of yields of sucrose shown in Figure 7 shows how slowly the secondaries develop when P is low. The plants were eight months old at the January harvest. At the final harvest in July, when the plants were 14 months old, the primaries of all groups yielded almost exactly the same amount of sucrose. But the secondaries of the control plants yielded almost three times as much sucrose as the plants in 2 ppm of P, which in turn produced 50 per cent more sucrose than the plants receiving 1 ppm of P.

The analyses at harvest of the 8–10 internodes showed that the plants on the low levels of P were definitely below the critical range for P. The values were 0.028 per cent and 0.012 per cent, respectively.

Figure 8 shows that the inorganic P is a more sensitive indicator of deficiency; and that the stalk internodes are more sensitive (per cent P low—per cent P very low) than the 3–6 sheaths.

PLANT TISSUES VARY IN REACTION TO PHOSPHORUS STRESS

In the fourth pot test of 1956–1957, extensive phosphorus analyses were made of four varieties. The summary of data in Table 5 shows how much alike the different tissues are when plants are growing in excess P. As the supply of P diminishes and levels restrictive to growth are reached, the different tissues drop to very different P contents. Basal internodes are most sensitive to changing supply, and 8–10 internodes are much more sensitive than the sheaths.

Table 5
Total Phosphorus in Roots Compared with Other Parts of Plant

Data summarized from 4th Pot Test, 1956–57, as per cent dry weight. Average of 4 varieties.

Part	ppm P in nutrient solution		
	32	2	1
Roots	.341	.169	.129
Tops	.255	.101	.076
Sheaths 3–6	.216	.066	.044
Internodes 8–10	.219	.028	.012
Basal internodes	.215	.014	.010
Millable cane	.219	.019	.012
Stubble	.221	.036	.024

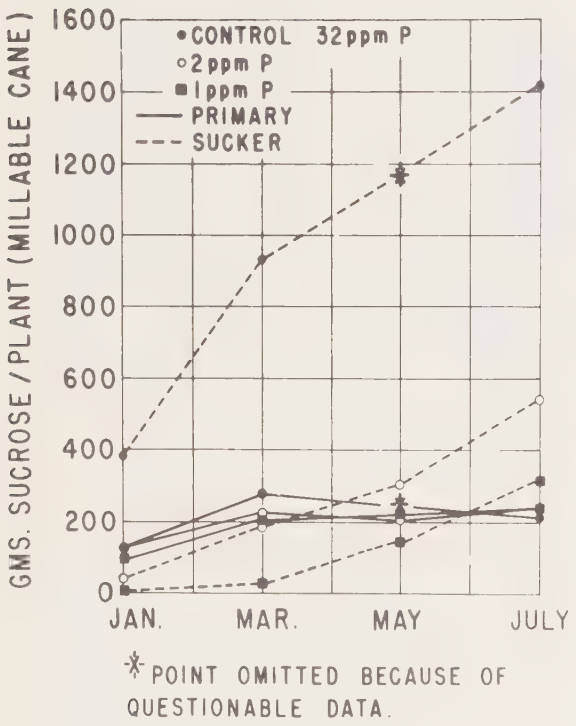

Figure 7. Effect of P on yield of sucrose in millable cane. The phosphorus supply had much more effect on the yield of sucrose in suckers than in primary stalks.

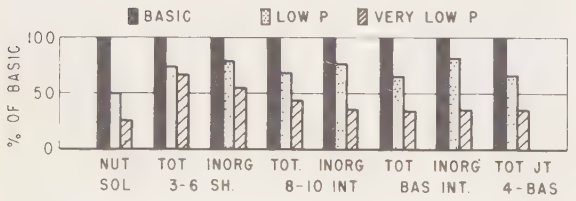

Figure 8. Relation between phosphorus supply and phosphorus composition of plants.

Roots contain more P than any other part of the plant and are much more difficult to starve. Under greatest restriction, the roots are 10 times as rich as the stalk. This high content of root P may be a reflection of the need for phosphorylation transport across the root tissue.

SOIL TEST RESULTS NOW REPORTED GRAPHICALLY

Owing to the sugar strike, the number of soil samples analyzed for available nutrients during the past year was very much smaller than during the previous year. The total for the year just past was 1315. The number of plant samples analyzed during the same period was 285, and of water samples, 340.

To facilitate the reporting of soil analytical data for phosphorus, potassium and calcium, a graphic presentation in place of the conventional type of report is now being offered to plantations. It is believed that this presentation will offer at a glance a more comprehensive view of the fertility status of a field than would follow examination of the tabulated data, and will also require less time in the preparation. An example of such a report for phosphorus is shown in Figure 9.

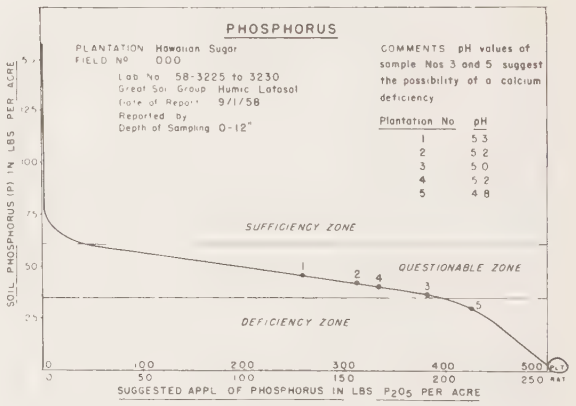

Figure 9. A graphic presentation of soil analytical data gives a comprehensive view of the fertility status of a field. The example above deals with phosphorus; potassium and calcium will be reported in the same manner.

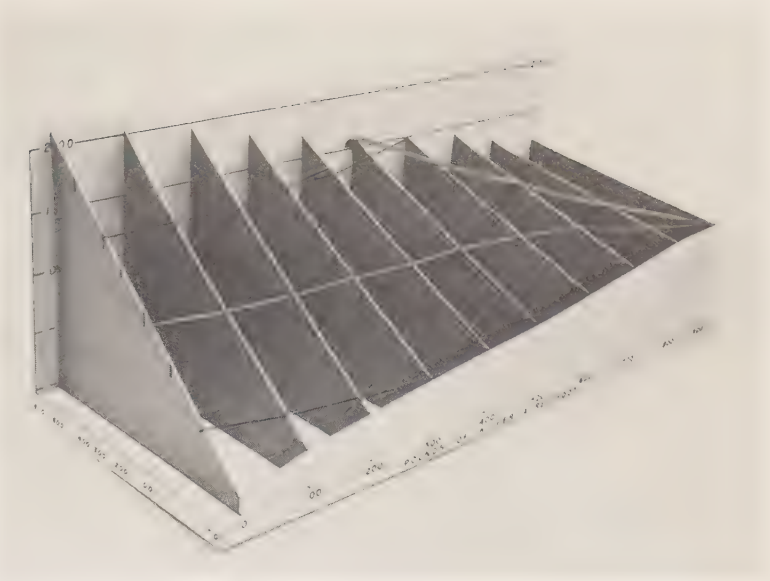

Figure 10. Yield response surface for potassium on the island of Hawaii. Yield deviations in TPA are on the vertical scale, with black and white contour lines denoting deviations of one TPA. The left-hand horizontal scale depicts the pounds of K_2O applied. The region to the left of the broad band represents profitable levels of K_2O application using a 10 per cent profitability index.

A NEW APPROACH TO DETERMINING OPTIMAL FERTILIZER LEVELS

A study of fertilizer response surfaces is currently under way as a joint project of the departments of Experimental Statistics and Agronomy. The data have been obtained from P and K experiments harvested on various plantations in the last seven years. Soil phosphorus and potassium data were also obtained from these experimental sites. The relationship between amount of P or K in the soil, amount of P or K applied, and yield response, is being determined. Figure 10 shows the form of the response surface for potassium on the island of Hawaii. In general, with low soil potassium a large response to added K is obtained, while with high soil potassium little or no response is realized from added K. Similar relationships are being investigated on the other islands for phosphorus as well as for potassium. These response surfaces will form the basis of an economic appraisal to determine optimal fertilizer levels.

NITROGEN AND POTASSIUM LEACH MORE ON ACID SOILS

Sulfate of ammonia has been found in laboratory studies to be more susceptible than some other nitrogen carriers to loss by leaching in acid (pH 5.0) hydrol humic latosols of the Puna region of Hawaii (Figure 11). On the average, 15 inches of water leached from these soils 53 per cent of the nitrogen applied as ammonium sulfate. The corresponding loss from urea was 29 per cent, and from aqua ammonia and Uramite three per cent. At 25 inches, losses from these carriers, in the order indicated, were 86, 60, 18 and 6 per cent.

Further evidence has been obtained that soils very low in base saturation have little ability to retain potassium against leaching when this element is applied as muriate. Additional evidence has also been obtained that, on soils of the nature indicated, potassium from the sulfate is less readily leached than potassium from the muriate. Evidence of these facts is presented graphically in Figure 12.

Laboratory studies with aqua potash on soils very low in base content have revealed the following:

1. Potassium from aqua potash is less subject to leaching than from potassium chloride alone.

2. Nitrogen from aqua potash is more subject to leaching than from aqua ammonia alone. These observations are illustrated in the case of potassium in Figure 13 and of nitrogen in Figure 14.

Liming acid soils very low in bases decreases the leaching of potassium from the chloride. This is illustrated in the case of a humic latosol in Figure

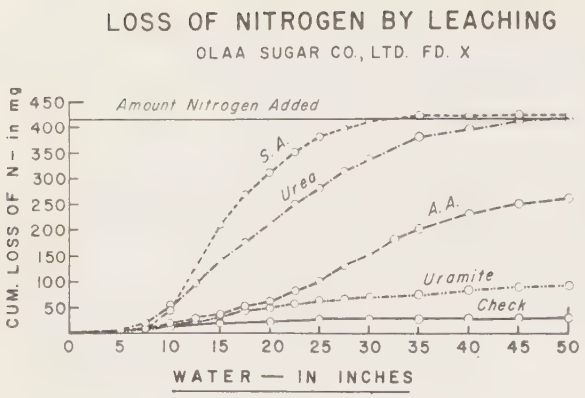

Figure 11.

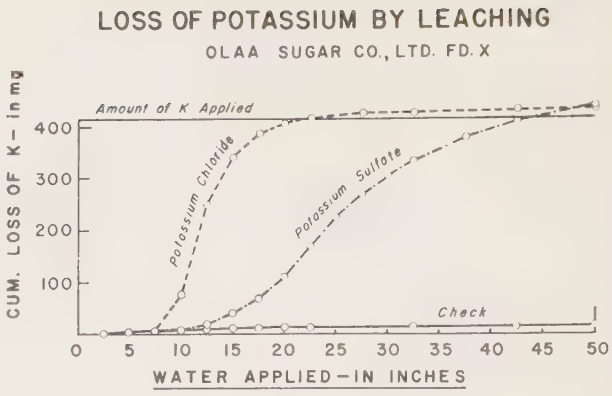

Figure 12.

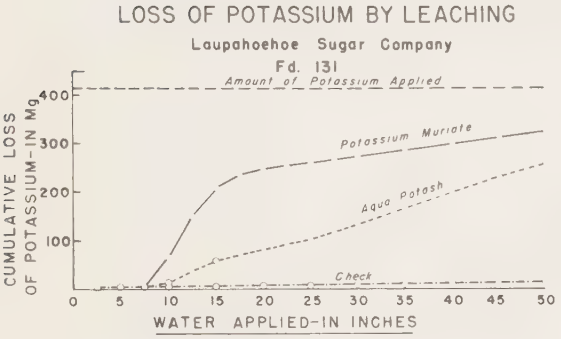

Figure 13.

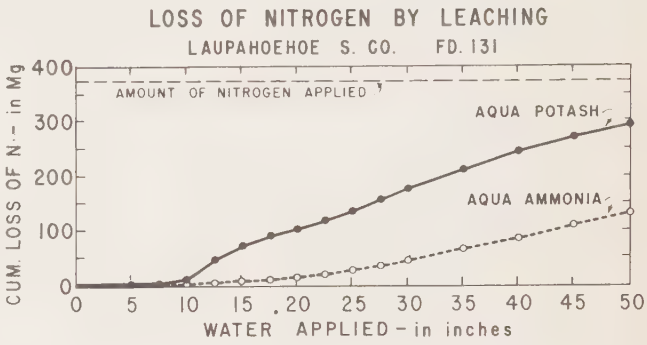

Figure 14.

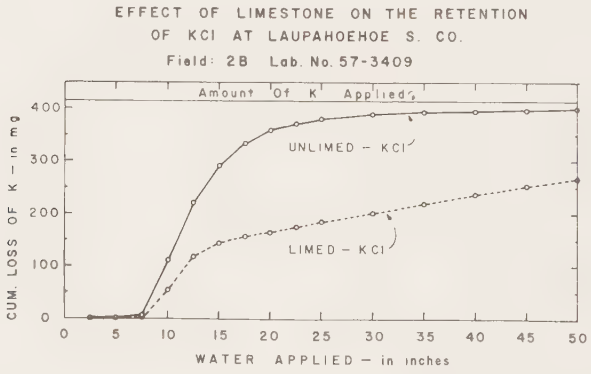

Figure 15.

15, where are shown cumulative losses resulting from the leaching of limed (two tons per acre) and unlimed soils which had received potassium chloride at the rate of 250 pounds K_2O per acre (415 mg. K per column).

LEACHING LOSSES IN HC&S LYSIMETERS

Analysis and measurement of water recovered from lysimeters at Hawaiian Commercial & Sugar Co., Ltd. have made possible determination of the

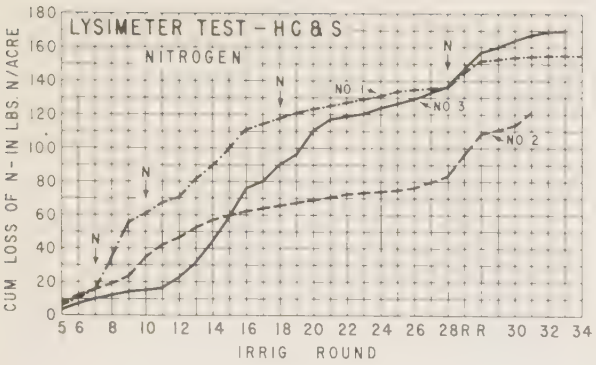

Figure 16.

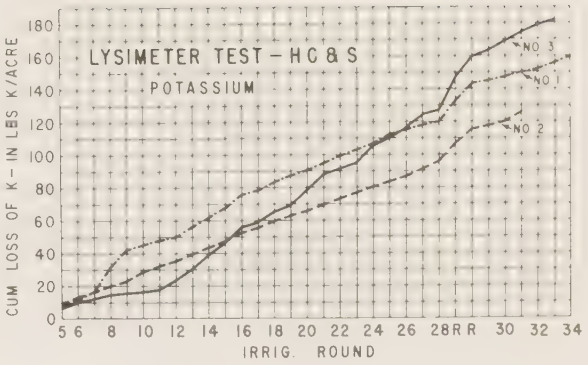

Figure 17.

losses of nitrogen and potassium which take place under the particular field conditions. For the three lysimeters which were first installed (Field 906) and which had received 33 rounds of irrigation, losses of nitrogen and potassium, respectively, averaged 150 and 155 pounds per acre. Rates of fertilization in this field were 340 pounds N and zero pounds K_2O per acre. Curves showing the cumulative losses of these elements are presented in Figures 16 and 17.

CALCIUM LEACHES FROM BIG ISLAND SOILS

Very few data are available regarding the susceptibility of calcium to leaching in Hawaiian sugar-cane soils. For this reason, the results of a laboratory study of two low-calcium humic latosols from the Hilo-Hamakua Coast area will be of interest. The results of the study presented in Figure 18, reveal losses of 20 and 45 pounds exchangeable Ca resulting from the passage of 50 inches of water through the soils. It will be noted that losses are directly related to the levels of (exchangeable) calcium initially present.

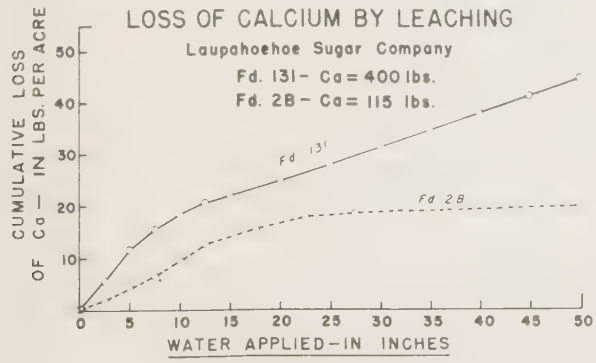

Figure 18.

Recently initiated liming programs in some of the wetter areas have called for a study of the susceptibility of ground limestone to leaching. A representative humic latosol was treated with limestone at the rate of two tons per acre, placed in leaching tubes, wetted and allowed to stand for a period of one and a half months to promote reaction with soil acids. The treated soils were subsequently leached over a period of one and a half months with 75 inches of water. The results of the test, shown in Figure 19, indicate an average loss of about 10 per cent of the amount of lime applied.

SULFATE LEACHING VARIES WITH SOIL TYPE

Studies initiated to explain the very high sulfate content of some soils in high-rainfall areas and the extremely low amounts of sulfate in many soils subject to only moderate leaching, have revealed widely varying abilities of Island sugar-cane soils to sorb, or retain, added sulfate. Curves showing cumulative losses of sulfate from potassium sulfate, for three soils from areas differing greatly in amounts of rainfall, are shown in Figure 20.

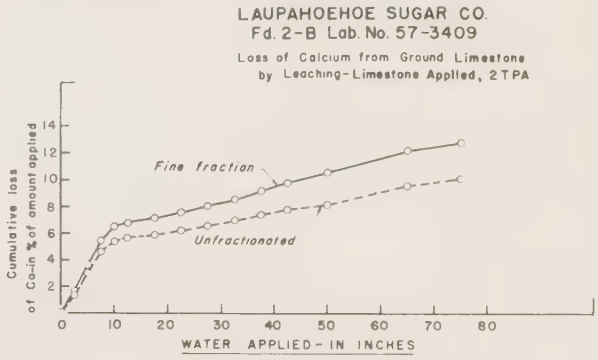

Figure 19.

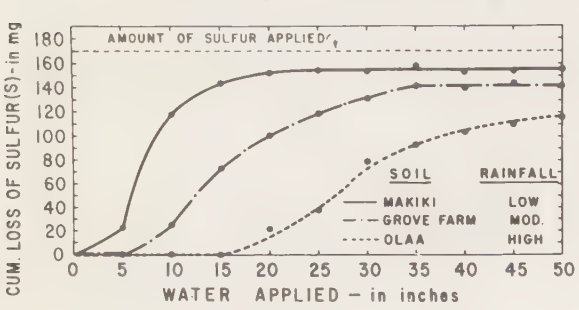

Figure 20.

NEW TECHNIQUES FOR STUDYING MINOR ELEMENTS

A method has been developed in this laboratory, based upon dilute acid extraction and subsequent spectrographic analysis, which is expected to provide a suitable means for establishing levels of "available" minor elements in sugar-cane soils. At present the technique has not been extended much beyond the reference soils initially selected for the study. Already, however, extremely wide ranges in supplies of some of the elements have been established, particularly with respect to manganese and iron. Very wide ranges in iron-manganese ratios have also been observed. The element aluminum, frequently assumed to be the cause of physiological disturbances in sugar cane grown on the more acid soils, is subject to close scrutiny by this method. Examples of the data being obtained are illustrated in Table 6.

SOILS VARY IN AVAILABLE SULFUR CONTENT

The departure from the use of sulfate of ammonia and sulfur-containing phosphate fertilizers on some plantations has led to a consideration of levels of available sulfur in soils. Results to date indicate that the sulfate-sulfur content of plantation soils ranges from a few to several thousand parts per million. Surprisingly, the lowest values appear to be associated with the irrigated areas, and the highest with regions of heavy rainfall. Some typical values for sulfur are presented in Table 7.

Table 7
Sulfate-Sulfur Contents of Hawaiian Soils

Great Soil Group	Location	Sulphur
		ppm
Low Humic Latosol	Makiki	5
Gray Hydromorphic	Ewa	6
Regosol	HC&S	13
Reddish Brown	Grove Farm	58
Humic Ferruginous Latosol	Kilauea	155
Humic Ferruginous Latosol	Grove Farm	230
Hydrol Humic Latosol	Olaa	235
Hydrol Humic Latosol	Laupahoehoe	1250
Hydrol Humic Latosol	Olaa	1960
Hydrol Humic Latosol	Onomea	2650

SULFUR DEFICIENCY IN SUGAR CANE

Four varieties of sugar cane were grown in nutrient solutions with and without added sulfur until symptoms of sulfur deficiency developed. The plants were then divided into blades, sheaths, mature, immature, and 8–10 stalk sections, and analyzed for sulfur, nitrogen, phosphorus and potassium.

Levels of sulfur in the various parts of the plant varied widely, and were invariably far higher in the plants grown in complete nutrient solution than in those grown in the absence of sulfur. In the 8–10 section of the stalk, levels of nitrogen and phosphorus in every instance were far higher in the minus sulfur plants than in those which received sulfur. Levels of potassium followed the

Table 6
Minor Elements in Hawaiian Soils

Lab. No.	Location	Great Soil Group	pH	Fe	Mn	Cu	B	Al	Fe/Mn	Al/Fe
				ppm	ppm	ppm	ppm	ppm		
57–2944	Grove Farm	Humic Ferruginous Latosol	5.0	33	14	7	2	3800	3.8	145.
58–647	Grove Farm	Humic Ferruginous Latosol	5.8	44	245	13	3	2050	.18	93.
57–2851	Hawn. Agr.	Brown Forest	5.6	1525	28	11	4	1125	54.	1.5
58–637	Kahuku	—	4.2	300	250	13	2	725	1.2	4.8
57–2891	Makiki	Low Humic Latosol	6.8	97	43	15	3	4250	2.3	87.
57–3411	Onomea	Hydrol Humic Latosol	5.0	350	29	11	5	4675	12.	27.
57–3410	Paauhau	Humic Latosol	5.3	81	15	17	3	3425	5.4	86.
58–350	Waialua	Low Humic Latosol	4.9	77	825	16	3	1050	.09	27.
58–636	Waipio	Low Humic Latosol	7.1	19	295	12	1	1475	.06	155.

same pattern, but in general, differences were much less pronounced. The appearance at harvest of one of the varieties (37–1933) is illustrated in Figure 21.

FERTILIZING CANE FROM THE AIR

The airplane continues to be an important tool in the application of fertilizer. In both 1956 and 1957, over 20,000,000 pounds of fertilizer were applied by air.

Over 3,500,000 pounds of fertilizer were applied on the island of Hawaii alone during the month of January in preparation for the strike. Following the strike, the airplane again proved invaluable in getting fertilizer on the cane in a minimum of time, so as to resume optimum rates of growth.

Modifications of the deflector vanes on the airplane distributors have resulted in improved application patterns. Cooperative studies with Murrayair Limited are continuing for further improvement.

PROTECTION AND MAINTENANCE OF SPRAYING EQUIPMENT FOR LIQUID FERTILIZER CONCENTRATES

Progress has been made in the research on the development of liquid fertilizer concentrates and of inhibitors of corrosion for use with the popular fertilizer concentrates.

A new liquid fertilizer concentrate was placed on the Mainland market during the latter part of 1957. It consisted of a solution of the nitrates of ammonia and calcium, and was described as a concentrate containing nitrate-nitrogen for quick plant response and ammonia nitrogen for long-season use.

There are several disadvantages involved in employing such a concentrate in Hawaii. Because of its explosive character, the ammonium nitrate would have to be brought into Hawaii already dissolved in water, thus adding considerably to transportation costs. Then, too, both calcium nitrate and ammonium nitrate are severely corrosive, particularly to iron, black iron, and steel.

To overcome these disadvantages, a concentrate was developed in the Chemistry Department which consisted of calcium nitrate in aqua ammonia, in which it dissolves readily and rapidly. It was found that 65 gallons of aqua ammonia (20 per cent N) would dissolve 600 pounds of commercial calcium nitrate in a relatively short period of time, producing 100 gallons of a liquid concentrate carrying 9.06 per cent of ammonia nitrogen, 6.56 per cent of nitrate-nitrogen, and 9.29 per cent of calcium as Ca. Muriate of potash may be included in this solution, if desired.

Figure 21. Sugar cane grown in nutrient solutions with and without added sulfur.

Although calcium nitrate alone is corrosive on ferrous metals, the solution of this chemical in aqua ammonia is not corrosive. It is conceivable that the advantages described by the Mainland manufacturer for his calcium-ammonia-nitrate concentrate may be found in the aqua-ammonia-calcium-nitrate solution developed at this Station. However, it is essential, in making up any formulation of mixed fertilizer constituents containing aqua ammonia, to use a closed system of preparation in order to prevent the loss of ammonia in the process.

Laboratory studies have shown that the addition of aqua ammonia to concentrated solutions of ammonium nitrate, muriate of potash, and calcium nitrate, will definitely arrest and

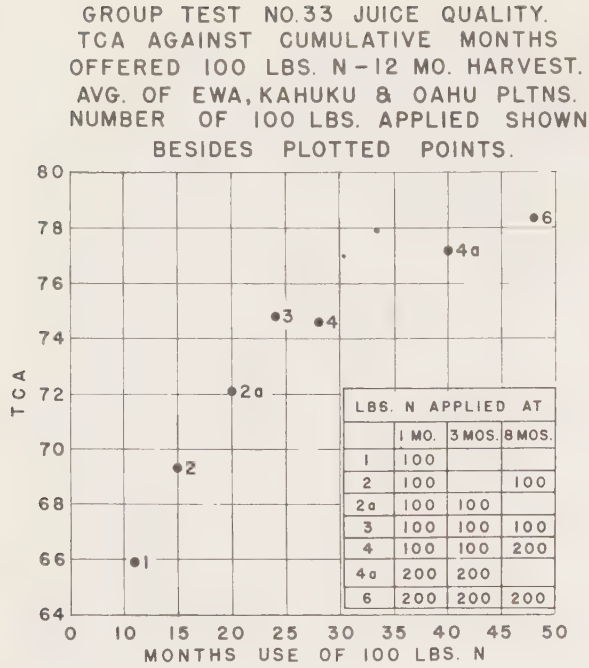

Figure 22.

prevent corrosion in steel containers, not only where the concentrated solutions are in contact with the metal, but above the solution level where the vapors are in contact with the container. In the case of a liquid concentrate of ammonium nitrate carrying 20 per cent nitrogen, the addition of as little as three per cent nitrogen in the form of aqua ammonia will maintain its 20 per cent level of nitrogen and, at the same time, establish and maintain a non-corrosive environment, not only in storage tanks but in steel and black iron application equipment. The loss of nitrogen by evaporation from ammonia is materially reduced in handling this concentrate because only 20 per cent by volume of the concentrate consists of aqua ammonia.

Muriate of potash may be dissolved in aqua ammonia, with or without the addition of water, depending on the desired concentrations of N and K_2O. In this connection, the Agronomy and Field Engineering Departments have set up a pilot plant for dissolving muriate of potash in aqua ammonia out of contact with the atmosphere, thus preventing loss of ammonia in the process. The same apparatus may be used in the case of calcium nitrate. The latter is available in pelleted form from Pacific Chemical and Fertilizer Company and is very easily brought into solution at a very high concentration. The addition of ammonia will arrest its corrosive properties.

The study of manufacturing, storing, and utilizing fertilizer concentrates is being continued, particularly where corrosion may be inhibited without using chemical compounds which have no fertilizer value.

SUGAR-CANE RIPENING

The juice quality test (Group Test 33) on the island of Oahu was maintained on all plantations except Waialua Agricultural Company, Ltd., where the tests could not be fertilized and irrigated according to schedule because of the strike. The three tests on this plantation were discarded because of this. The three oldest tests, now 17 months old, have had microplots harvested at 12 and 15 months of age. Results of the 12-month harvest indicate excellent response to the amounts and time of application of nitrogen in TCA, as shown in Figure 22. The effect of amount and timing of nitrogen on juice quality was not clearly defined at this age. Figure 23 shows the aqua ammonia and aqua potash dispensing apparatus used in this experiment.

A study of the effect of percentage of poor stalks (dead and dying, sound but without tops, and rat damaged) on juice quality was conducted on the 12-month microplots harvested in the juice quality test (Figure 24). Juice quality was found to decrease as the per cent poor stalks increased.

Stalk census studies and pol ratio analyses of preharvest samples have proved effective and are being used on a number of plantations to help indicate the order in which fields should be harvested. These procedures were particularly effective in evaluating cane condition on those plantations which suffered most from the strike. The juice purity and tons cane per ton pol correlated very well with per cent dead and dying cane, as shown in Figure 25.

DRY SEED GERMINATES WELL

Germination studies conducted at Waipio with two sugar-cane varieties, comparing dry seed from Oahu Sugar Company, Ltd. and Ewa Plantation Company with normally-irrigated seed from Waipio, showed the dry seed to be superior to the normal seed in the case of 37–1933. Variety 37–

Figure 23. Apparatus for dispensing aqua ammonia and aqua potash.

1933 seed cut from cane at Ewa with only two or three green leaf tops had 83 per cent germination of the top seed and 81 per cent germination of the butt seed in three weeks time. The stand of cane from the dry seed was uniformly green and healthy. Early growth was faster with dry seed than with normally-irrigated seed in these tests, as shown in Figure 26.

With variety 49–5, the normally-irrigated seed was slightly better than the dry seed.

Figure 24. Planted in microplots for juice quality studies, primary stalks have been painted so that they may be separated from suckers at harvest.

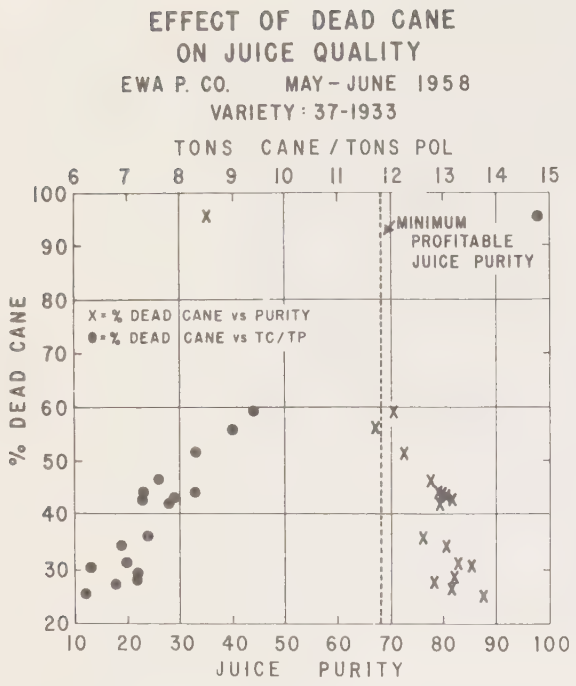

Figure 25.

Figure 26. Effect of drought on seed cane germination: Seed of Variety 37-1933 (left center) came from drought-stricken plants with only two to three green leaf tops. It showed 83 per cent germination of top seed and 81 per cent germination of butt seed in three weeks. Note the comparison in size and number of stalks with plants from normal seed at right center.

STARCH IN SUGAR-CANE PLANTS

Because of a renewed interest in starch as a possible factor in raw sugar quality, data from nitrogen study #1 (1947) have been recalculated and plotted.

Results of this experiment were tabulated for the purpose of illustrating the relative importance of starch in the sugar-cane plant, since this experiment produced our most complete data on starch.

Starch was determined on the residue after extraction of soluble sugars. An aqueous solution of saliva was used to extract the starch, which was then hydrolyzed by acid. An invertase control was run and subtracted from the acid hydrolysis, giving the saliva-soluble polysaccharide, or starch.

The spindle, blades 4, 8, 12, sheaths 4, 8, 12, and cane joints 0–3, 4, 8, 12, 16 and 20, were analyzed separately for sucrose, glucose, fructose, starch, and residual hydrolyzable polysaccharides. Results for one harvest are graphed in Figure 27.

Highest percentage of starch in the control plants, variety 32–8560, sampled April 9, was in the growing point (cane joints 0–3) with 1.180 per cent starch (dry weight basis). The starch decreased down the stem to 0.084 per cent in joint 20.

FIRST STEPS IN A CANE PLANT'S FACTORY

The study of photosynthesis has resulted in solving the discrepancy between results in this laboratory and those of other workers on the identification of PGA, using an unambiguous synthesis of 1-glyceric acid. Samples purchased as glyceric acid from several suppliers were found to be wrongly identified as such.

In several tests, sugar cane produced PGA as the first stable phosphorylated photosynthetic product.

The results of a test with radioactive carbon (RC 72) are given in Tables 8 and 9. The exposure to bright light after introducing $C14O_2$ into the chamber was for 15 seconds.

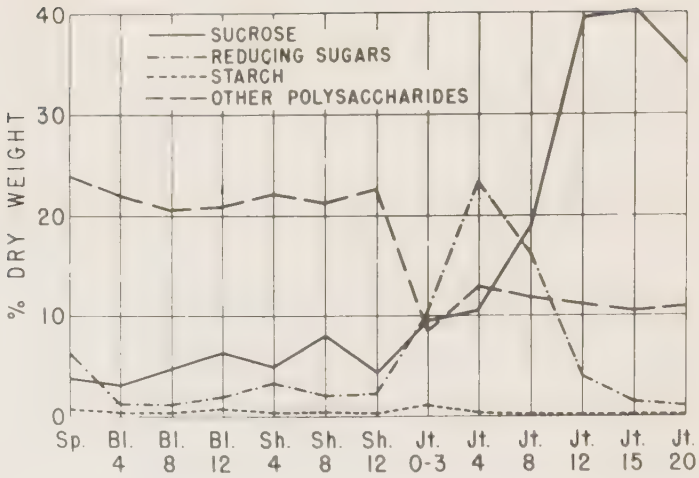

Figure 27. Carbohydrates in Variety 32-8560 were graphed as per cent dry weight when the cane was seven months old. The amount of starch is relatively small in comparison with amounts of other carbohydrates.

Table 8
% of Grand Total Counts

	Primary	Sucker	Seedling
PGA	17	12	21
Malic	40	30	39
Aspartic	18	33	18
Sugars	—	4	1

Note that the sum of the counts in the 4-carbon compounds, malic and aspartic acids, varies only between 57–63%.

Table 9
Total Counts in Compounds

	Primary	Sucker	Seedling
PGA	8,000	9,000	28,000
Malic	18,000	22,000	53,000
Aspartic	8,000	25,000	24,000
Sugars	—	3,000	1,000
Total Identified	34,000	59,000	106,000
Grand Total	46,000	75,000	135,000

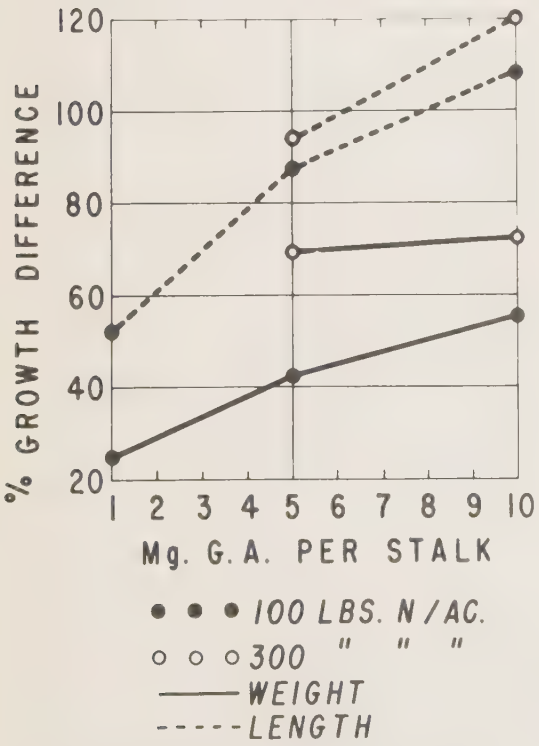

Figure 28. Effect of gibberellic acid on cane growth.

The only strongly labelled compounds found were PGA, and aspartic and malic acids. There are very small counts in free glyceric acid, phosphomalic acid, and sugar phosphates. The primary leaf had counts too low for accurate determinations.

GIBBERELLIC ACID TESTS CONTINUE

The 12 plots at Makiki that receive continued application of gibberellic acid are well into their second year. Harvest for yield data is set for next June 1.

In these plots, nitrogen is being maintained at a very high level to assure that the gibberellic acid has full opportunity to induce maximum growth. Figure 28 shows how cane receiving 100 pounds of nitrogen per acre could not respond fully to the applied gibberellic acid. This was especially true of the increase in weight.

DISEASES

DISEASE RESISTANCE TRIALS INSPECTED IN FIJI

The varietal resistance trials in Fiji, where Hawaiian varieties are being tested against Fiji disease and downy mildew, were inspected in June 1958. The quarantine area for growing canes imported into Fiji had been transferred from Yaqara to Bekana Island, which is approximately two and one-half miles offshore from the Lautoka Mill. In November 1957, 24 Hawaiian canes were sent to Fiji and planted in the Bekana quarantine area, followed by a second lot in June 1958. These varieties will be tested after their release from quarantine.

The highest degree of Fiji disease transmission occurred in the Murisara trial, followed by those at Labasa, Lautoka, and Malomalo. The leafhopper populations were found to be very high in most testing areas.

As the result of adverse weather conditions and the low incidence of downy mildew, it was impossible to evaluate the reaction of all varieties to this disease in the 1957–1958 trials; varieties manifesting 10 per cent or more of infection will not be retested. Based on the results from the disease trials conducted in Fiji, Samoa and Australia, the reactions to Fiji disease and downy mildew of the 25 Hawaiian varieties occuping 100 acres or more as of December 31, 1957, are listed below.

	FD	DM		FD	DM
31–2484	−	+	44–2772	−	+ +
32–1063	− −	= +	3098	−	−
8560	−	+ +	45–2120	−	= +
37–1933	= +	+	2708	−	= −
38–2915	− −	= −	2608	= +	= +
4443	− −	+	46–564	+	+ +
39–3633	+	+	48–3845	(1)	
4753	− −	+	4178	+	=
5803	= +	= +	49–5	(1)	
7028	= +	+ +	104	−	+
40–1179	− −	+	134	=	= −
41–3340	− −	=	612	+	=
			3533	+	−

(1) Now being tested in Fiji.

The disease of greatest concern in Fiji is Fiji disease, and every effort is being made to control it by planting resistant varieties, selecting healthy planting material, and roguing diseased plants. A systematic roguing program has been inaugurated at the Lautoka Estate in order to reduce sources of the disease in fields and in areas used for planting material.

The disease of second greatest concern in Fiji is downy mildew, which is being controlled through the use of resistant varieties. The two major commercial varieties in Fiji are Ragnar and Pindar; both are highly resistant to downy mildew; Ragnar is highly resistant to Fiji disease, whereas Pindar is moderately susceptible.

MANY CANES PASS THROUGH MOLOKAI QUARANTINE

All newly-imported canes under greenhouse and field quarantine were inspected periodically for symptoms of diseases foreign to Hawaii. One lot of 19 canes introduced in 1955, having completed the two-year quarantine, was released for planting at the substations. Another lot of 23 canes imported through the United States Department of Agriculture was planted in the small quarantine house in November 1957. No symptoms of any diseases foreign to Hawaii were noted on the canes while under quarantine.

THE 1958 DISEASE PICTURE

Plantation inspections in 1958 indicated that the major problems were associated with red rot, yield decline, soil fumigation and nematodes.

The disease of greatest concern was **red rot,** which now occurs on each island.

Chlorotic streak was still of major importance in the heavy rainfall areas; seed selection and the hot-water treatment of planting material are the best measures to follow for controlling it.

Pineapple disease caused poor germination in a few instances; the PMA treatment still continues to be an effective control.

Ratoon stunting was not found to be widespread, and has not been found in varieties of commercial plantings during the past year. Seed selection and establishment of disease-free areas

with treated cuttings (long hot-water treatment, 50° C. for 2 hours) as seed sources have aided in reducing the incidence of the disease.

Sour rot was of major importance in fields which suffered severely from drought as the result of the 1958 sugar strike. It has caused a marked reduction in juice quality in affected fields.

Leaf scald was of no economic importance; only a few scattered cases were recorded.

RED ROT CAUSES GREAT CONCERN

Red rot disease now occurs in fields of 38–2915 on one or more plantations on each island. The seriousness of the disease and the symptoms, causal organism, transmission, control of and varietal reaction to the disease, have been covered in earlier reports. Within the past two years, some 72 varieties have been tested against red rot on Oahu, Kauai and Hawaii; 38–2915 proved the most susceptible of all varieties tested.

Red rot has not been observed on any commercial variety other than 38–2915. The reactions of the varieties tested at The Lihue Plantation Company, Ltd., Waialua, Kekaha Sugar Company, Ltd., Hamakua Mill Company and the Pathology Plot follow:

Variety	Rating	Variety	Rating	Variety	Rating
32–8560	+	48–3845	+	50–2606	+
37–1933	+	4178	+	2746	+
38–2915	−−	4605	+	3861	=−to−
38–4443	=+to+	4646	=+	4509	+
39–3633	++	4899	+	4936	+
4753	+	49–5	+	5028	=to=−
5803	=+to+	104	+	5217	+
7028	+	118	+	5386	+
41–1045	+	134	+	6062	+
3340	+	612	=+	6822	=+to+
44–2772	+	2113	+	6877	+to++
3098	+	3404	+	7209	=+
3171	+	3533	+	51–1047	+
45–2120	=+to+	3637	+	2530	+
2608	+	3666	+	4187	++
2708	=+to+	3736	+	4336	+
2860	+	3945	+	4768	=+
46–564	=+	3961	+	4964	+
3037	+	4638	+	5017	=+
47–1992	+	50–723	+	8194	+
48–152	=+to+	2036	+	8420	=−
514	+	2145	+	52–3683	+
527	+	2524	+	6449	+
546	+to++	2542	+		

New strains of fungi occur as a result of mutations, which explains why a resistant variety may become susceptible to a disease. In view of the development of new pathogenic mutants of red rot, periodic testing of varieties must be continued.

It may be concluded that the majority of the present-day commercial and breeding canes are resistant to the strain or strains of red rot now prevalent in Hawaii, and that most of their hybrids will possess similar characteristics. The ultimate control of the disease will be effected by the use of resistant varieties. The fields now affected with red rot should be given first consideration for replanting with resistant varieties.

The red rot organism, *Physalospora tucumanensis*, has been isolated from each plantation where the disease has occurred and is maintained in pure culture. Each isolate is treated as a separate strain and is not taken from one plantation to another, the theory being that the strains may be different and that one may be much more infectious than another.

SEARCH CONTINUES FOR METHOD OF TRANSMITTING CHLOROTIC STREAK

In previous years, transmission studies of chlorotic streak disease in nutrient-water cultures have indicated that the disease is root-transmitted. However, in December 1957, chlorotic streak symptoms developed on leaves of healthy plants growing in three pots with no root contact with diseased plants, although plants with chlorotic streak symptoms were growing in adjacent pots. A heavy infestation of the sugar-cane aphis developed on these plants. Since a high percentage of chlorotic streak transmission has been obtained in water culture studies, this appears to be an optimum medium for the expression of the symptoms. Very little transmission of chlorotic streak disease has been obtained with plants growing in soil. Further progress in these studies necessitates the use of a screened house.

SEED TREATMENT FOR PINEAPPLE DISEASE

Damage to cuttings from pineapple disease has been at a minimum during the current season because of the continued use of PMA treatment and because environmental conditions were favorable for germination.

Ten new fungicides were tested against the pineapple disease organism, *Ceratocystis paradoxa*, in the laboratory; the organic mercurials were the most effective of the chemicals tested. Several of these are being compared with PMA in field trials.

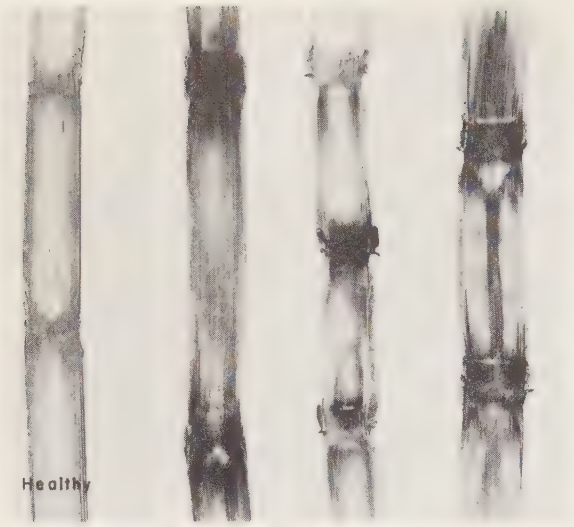

Figure 29. Sour rot, caused by the rind disease organism, **Pleocyta sacchari,** affects cane under stress from drought or overmaturity, first at the nodes, which turn reddish to brown in color, and later at the internodes, which assume a light brownish color. Whitish areas frequently occur in the growth band and are sometimes confused with symptoms of red rot disease.

STRIKE ACCENTUATED RIND DISEASE

Deterioration studies of sugar cane by sour rot following prolonged drought were made soon after the strike during which time the fields were not irrigated (Figure 29). Isolations from stalks with sour rot symptoms gave pure cultures of a fungus. Inoculation of steam-sterilized portions of stalks in petri dishes showed this fungus to be *Pleocyta sacchari* (Figure 30), which causes rind disease of sugar cane when the cane is overmature or suffering stress from extreme drought conditions.

Cane growing normally is not attacked by rind disease, and the irrigation of cane deteriorating from sour rot will retard further development of the disease except in stalks either overmature or already severely affected.

PYTHIUM ROOT ROT CONTROL ON CANE SEEDLINGS

A systemic fungicide labelled "Bayer 22555", furnished by Chemagro Corporation, was highly effective for the control of *Pylhium* root rot when applied to growing cane seedlings as a drench at the rate of one gram in a liter of water per flat. This material stopped the spread of the disease when applied after some plants in the flat had become affected (Figure 31). The results suggest that one application of Bayer 22555 might be made to seedlings prior to moving them from the glasshouses, and that subsequent treatments be made only if the plants become affected with *Pythium.*

FUNGI IN PLANTATION SOILS CATALOGUED

An extensive survey was made to determine the numbers and types of fungi present in soils from a total of seven different plantations on Oahu, Hawaii and Kauai. These soils varied in number of years in cane, pH, per cent organic matter, elevation, and irrigation versus no irrigation.

In view of the numerous factors involved, it is difficult to draw definite conclusions from such a study. There were many instances where the fungus population was lower in pasture and pine-forest lands than in adjacent sugar-cane field soils, but the reverse was true in other cases. In almost all cases, a very low *Trichoderma* fungi population was noted in the pasture or virgin forest soils as compared to that in the adjacent sugar-cane soils, indicating that these fungi, which are parasitic on some damping-off fungi, including *Pythium*, tend to increase in numbers in fields under cultivation.

As indicated by results obtained from a modified boiled-hempseed method for trapping pythiaceous fungi, there were no appreciable differences in the number of pythiaceous fungi in uncultivated and cultivated soils.

FUMIGANTS AFFECT SOIL MICROORGANISMS

Results of laboratory studies, which were continued to compare the effects of DD (1:3-dichloropropene + 1,2-dichloropropane) and other fumigants on soil microorganisms, indicate that Vapam

Figure 30. Rind disease developed on sterilized portions of the cane plant, both leaf and stalk, following inoculations with isolates from cane stalks affected with sour rot.

Figure 31. As a control of **Pythium** root rot of sugar-cane seedlings, Bayer 22555, at the rate of 500 ppm of the active chemical, was applied as a drench along the front of the center and right-hand flats of sugar-cane seedlings inoculated with the disease. It was applied again after **Pythium** had developed at the point indicated by the stake in the center flat. Considerable root rot developed in the no-treatment flat.

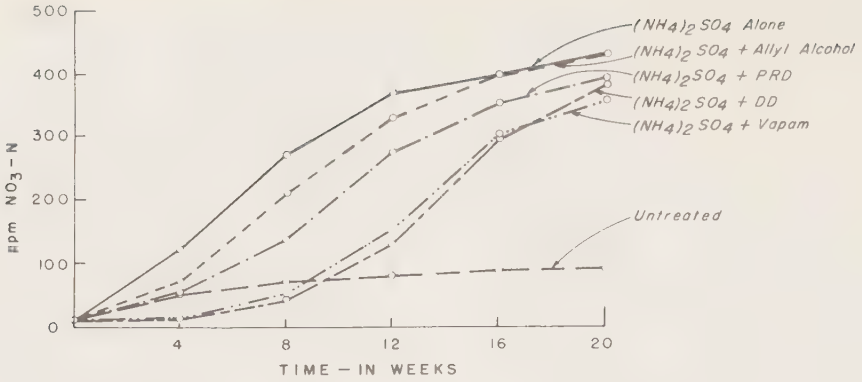

Figure 32. Accumulation of soil NO_3-N after applications of $(NH_4)_2SO_4$ plus no-fumigant, DD, Vapam, allyl alcohol and PRD, respectively.

(sodium N-methyl dithiocarbamate at 50 GPA) was, for all practical purposes, as effective as DD (40 GPA) in completely inhibiting nitrification of added $(NH_4)_2SO_4$ (500 parts N per million parts soil) for at least eight weeks (Figure 32). PRD (3:4-dichlorotetrahydrothiophen 1:1-dioxide at 40 pounds active per acre) and allyl alcohol (20 GPA) were less toxic to the nitrifying bacteria, no complete inhibition of nitrification being observed. Allyl alcohol was the least toxic of the fumigants tested; at the end of 16 weeks, the total amount of NO_3-N which accumulated in soils treated with allyl alcohol plus $(NH_4)_2SO_4$ was equal to the amount which accumulated in soils treated with $(NH_4)_2SO_4$ alone.

As indicated in Figure 33, the rates of nitrification in soils treated with DD or Vapam were extremely low during the 0–4 week period, but began to increase during the ensuing periods; during the 12–16 week period, the rates of nitrification in soils treated with DD and Vapam increased markedly and were equal to (in the case of Vapam) or slightly greater than (in the case of DD) the rate observed for the $(NH_4)_2SO_4$ control soils during the 4–8 week period. The maximum reached during this period is, no doubt, due to an increase in numbers and activity of the nitrifying bacteria after an initial inhibition, and also to the large amount of NH_4-N still available in the fumigated soils.

In the case of allyl alcohol, the rate of nitrification was almost equal to that of the $(NH_4)_2SO_4$ control soils during the 4–8 week period, and exceeded that in the $(NH_4)_2SO_4$ control soils during the ensuing 8–12 and 12–16 week periods.

The decrease in the rate of nitrification of

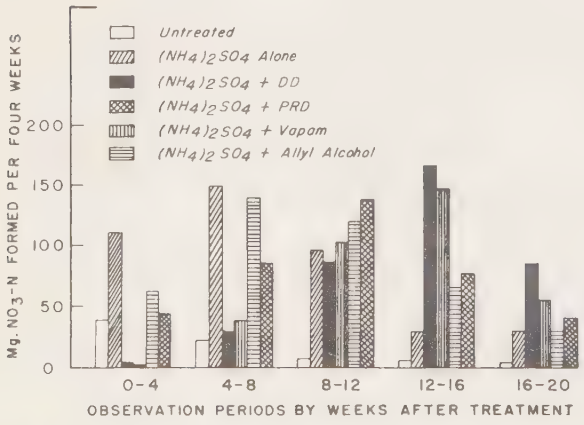

Figure 33. Changes in the rate of nitrification of $(NH_4)_2SO_4$ after soil fumigation with DD, Vapam, allyl alcohol and PRD, respectively.

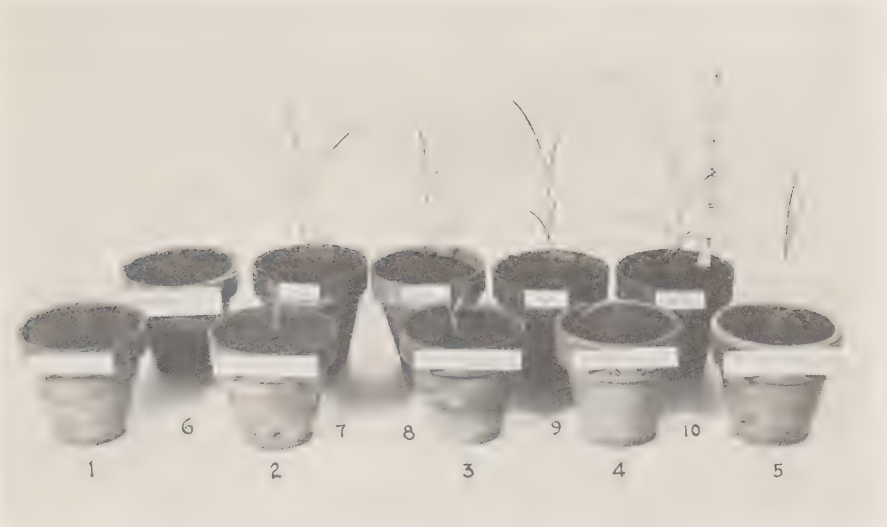

Figure 34. The effects of **Trichoderma** isolates (7, 8, 9, 10), **Pythium** (1), and combinations of **Trichoderma** isolates and **Pythium** (2, 3, 4, 5) upon the growth of sugar-cane seedlings, are shown in comparison with the uninoculated control.

$(NH_4)_2SO_4$ was slightly greater with PRD than with allyl alcohol during the 0–4 and 4–8 week periods, and the maximum rate of nitrification in soils with PRD + $(NH_4)_2SO_4$ was observed during the 8–12 week period.

An interesting observation was the 90 per cent reduction in the total numbers of fungi, which persisted for about 20 weeks, in soils treated with Vapam; the *Trichoderma* fungi population was also markedly reduced, being only a fraction of that in other soils. Other fumigants had little or no effect on the total numbers of fungi, but allyl alcohol was found to increase the *Trichoderma* population one and a half to four times that present in the soils containing other treatments at the expense of some other species. Allyl alcohol is known to create conditions in soil favorable for the development of *Trichoderma*, and this high population of *Trichoderma* may account for the effectiveness of the chemical in the control of damping-off organisms, as reported in the literature.

All of the fumigants appeared to cause a temporary slight increase in the numbers of bacteria.

HOW FAR DO FUMIGANTS KILL?

Results of profile studies conducted at Hamakua Field 16 indicate that methyl bromide at the rate of one pound per 100 square feet caused a marked increase in the number of bacteria, including actinomycetes, within a zone roughly six inches around the point of injection (seven inches below the surface), which persisted for at least 22 weeks (initial counts on bacteria + actinomycetes and fungi were made four weeks after fumigation). The fumigant caused a marked reduction in the total population of fungi for at least 14 weeks within a zone at least six inches around the point of injection.

The *Trichoderma* population increased within only a narrow band around the point of injection at the end of four weeks, but markedly increased after about eight weeks within a zone five inches vertically and downward from the point of injection but less than four inches laterally. After 14 weeks, the vertical and downward zones of stimulation were narrowed, but the lateral zone of stimulation was slightly increased. This discrepancy may have been caused by an uneven diffusion rate of the fumigant through the particular profile.

DD caused a marked increase in the total numbers of bacteria, including actinomycetes, roughly five inches around the point of injection, which was most noticeable four weeks after fumigation, the time of initial sampling. The total population

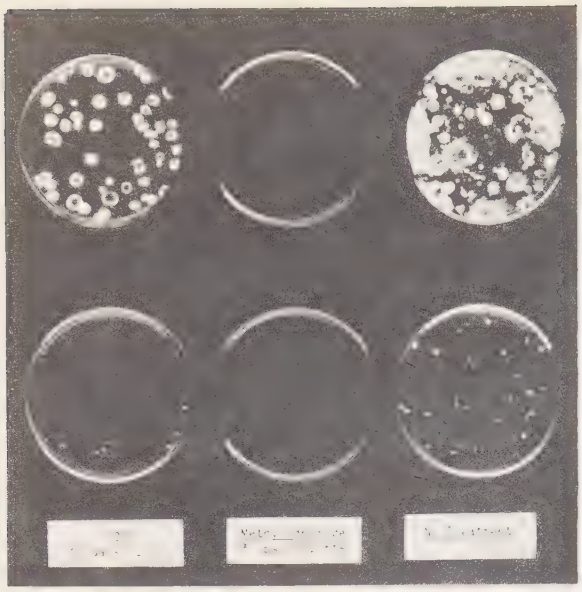

Figure 35. The effects of fumigation are shown on soil fungi (upper row) and on bacteria (lower row). Note complete control given by methyl bromide. (Soil from Field Opaeula 9, Plot 20, Waialua)

of fungi was only slightly affected, but after 14 weeks, the *Trichoderma* population had increased and exceeded the numbers present in the control soils within a zone about five inches around the point of fumigation.

EFFECTS OF TRICHODERMA ON CANE GROWTH

Two separate tests were conducted to study the effects of several *Trichoderma* spp. isolates from fumigated soils on the growth of sugar-cane seedlings planted in steam-sterilized soil in three-inch clay pots.

Results of the first test (Figure 34), using an Ewa (Field 57) soil of pH 7.0, indicated that the *Trichoderma* isolates failed to inhibit *Pythium* root rot of the cane seedlings, with the exception of isolate W-28, which appeared to have inhibited the damping-off of the seedlings. The growth of seedlings in pots with *Trichoderma* isolates alone (without *Pythium*) appeared to have been stimulated.

A Hamakua soil (Field 16, Area A) of pH 5.0 and *Trichoderma* spp. isolated from the fumigation tests in this area, were utilized in the second test. Results of this test revealed no inhibitory action of the *Trichoderma* isolates against *Pythium;* furthermore, no stimulatory or inhibitory effect on cane growth by the *Trichoderma* isolates alone was noticed. The effects of the *Trichoderma* isolates on *Pythium* and cane growth will be further investigated during the coming seedling season, inasmuch as the *Trichoderma* fungi are considered one of the important groups of microorganisms which are antagonistic to some of the root-infecting fungi inhabiting the soil. No doubt numerous factors in the soil affect the antagonistic activity of the *Trichoderma* fungi.

VISITING NEMATOLOGIST UNCOVERS MANY FACTS

Dr. Harold J. Jensen, Nematologist, Oregon State College, spent six months at this Station investigating the role nematodes are playing in the varietal yield decline problem. A summary of his findings includes:

1. Eight genera of plant parasitic nematodes were found associated with sugar-cane root systems. Three of these (root-knot, root-lesion and spiral nematodes) are believed to be the most important.

2. The growth of seedlings in pot studies was reduced by 30 to 60 per cent when exposed to various combinations of nematodes. Adverse growing conditions may be necessary to demonstrate a similar effect when cane cuttings are used, due to the reserved food stored in the seedpiece.

3. The population of parasitic nematodes within a field appears to have reached its highest peak during the first eight to 10 years of cane production.

4. Nematodes were found in much greater num-

Figure 36. A power rig for injecting fumigants into the soil under pressure is mounted on a Terratrac tractor. Working under field conditions at Hamakua Field 16, this rig has fumigated areas which were cultipacked, and other areas which were covered and not covered with tarpaulins, to determine the maximum efficiency of methyl bromide in control of both weeds and soil organisms in cane fields.

bers in soils on the non-irrigated than on the irrigated plantations.

5. The failure of sugar cane to respond to fumigation may be attributed to spotty distribution of nematodes, improper soil preparation, seasonal fluctuations of nematode populations, behavior of fumigants in the soil, and optimum dosage of fumigants.

On a grant made available to this Station by the Shell Chemical Company, Dr. Walter J. Apt, Associate Nematologist, USDA, Western Washington Experiment Station at Puyallup, will continue with the studies initiated by Dr. Jensen.

FUMIGATION RESEARCH CONCENTRATED AT HAMAKUA MILL COMPANY

An experimental area of approximately two acres was acquired at Hamakua and tests have been installed for studying seasonal fluctuations in nematode and fungi populations for evaluating standard and new fumigants and determining optimum dosages and methods of application. Methyl bromide applied at the rate of three pounds per 100 square feet completely inhibited the growth of soil fungi and bacteria (Figure 35).

Preliminary cooperative tests for the control of weeds, weed seeds and harmful soil microorganisms with methyl bromide injected into the soil, were installed at Hamakua Field 16 by the Agronomy and Pathology Departments. The Field Engineering Department was responsible for assembling the injection equipment which was mounted on a lightweight track-type tractor. Additional equipment included a methyl bromide injection unit, a direct-mounted 16-inch Teflon-covered moldboard plow, and a six-foot cultipacker. Personnel from Dow Chemical Company, Pacific Chemical & Fertilizer Company and Hamakua assisted with the installation of the tests (Figure 36). Materials were furnished by the two chemical companies. For a report on the weed control aspects of these tests, see page 71.

FACTORY

ECONOMICS OF IMPROVED EXTRACTION BY MILLING AND BY DIFFUSION STUDIED

A study of the economic factors involved in recovering additional sugar from cane by improvements in extraction and by application of the diffusion process was completed. The report shows that in many cases it would be sound economics to make the capital expenditures necessary for improvement in the present mills to achieve a higher extraction.

For the industry as a whole, the economic potential of extraction by diffusion is more attractive. If a continuous diffusion process were developed which would obtain results similar to those realized by the beet sugar industry, the average annual savings would pay off the capital investment in about three years.

The report shows further that if a cane harvesting method were perfected that would allow field cane to be processed without cleaning, the annual savings would be doubled.

CANE DIFFUSION PILOT PLANT UNDER CONSTRUCTION

At midyear, a cooperative program for investigating the recovery of sugar from cane by diffusion was initiated. A pilot plant capable of treating 25 tons of cane per hour will be set up at Kekaha. The basic diffusion equipment, as well as engineering assistance, will be supplied by the Silver Engineering Works. Rietz Manufacturing Company is redesigning Prebreaker units for preparation of cane, and Merrick Scale Manufacturing Company is providing a continuous weighing scale.

The equipment is expected to be ready for operation at the start of the 1959 grinding season. Various methods of cane preparation will be studied. Processes of dewatering bagasse are included in the program.

NEW PRINCIPLE APPLIED TO PREPARATION OF CANE FOR DIFFUSION

Difficulty in preparation has been the major obstacle to the application of continuous diffusion processes to the extraction of sugar from cane. The only type of machinery which has appeared promising has been the shredder. Material prepared by such machines has two undesirable characteristics. The shreds tend to be too long and become tangled in conveying, and the material is fluffed up so that it is of relatively low density.

An entirely different approach to preparation has been tried and appears to have considerable merit. This uses a high torque, low-speed machine, similar in principle to a meat grinder. Rietz Manufacturing Company produces machines of this type, called Prebreakers, which are used for crushing, breaking, and shredding varied types of materials such as wood, bone, and ores.

A half-ton sample of cane was shipped to Santa Rosa, California, in April, and tests were conducted with representatives of Silver Engineering Works and of the HSPA present (Figure 37). Standard machines ground up cane to a product having a density of 20 to 30 pounds per cubic foot. Approximately 80 per cent of the cane was in suitable size range for diffusion. The large pieces present would require removal by screening and reprocessing. It was felt, however, that changes in the design of the machine which would eliminate these over-size pieces were possible.

The material handled well in an eight-foot model of a double scroll diffuser built by Silver engineers for the test work.

IMPURITIES IN SUGAR CRYSTAL INCREASE WITH GROWTH OF CRYSTAL

Observations on the quantity of impurities within the raw sugar crystal have shown that, in general, the larger crystals contain more im-

Figure 37. Cane processed in a Prebreaker passes through a demonstration diffusion unit.

purities. This is true of color, ash, and methanol insoluble matter. It has been reported also for moisture. Figure 38 shows the amount of color and ash in the crystals of various sizes of commercial raw sugar from a single strike.

This evidence supports the conclusion that occurrence of nonsucrose material within the crystal is due more to entrapment than to adsorption. Irregular growth, channeling, development of secondary faces, and fracturing, all increase as the size of the crystal increases. These phenomena tend to cause occlusion of mother liquor and hence all the impurities of molasses. The importance of crystal growth studies in the sugar quality program is indicated.

COLOR-BEARING COMPOUNDS AND OTHER ORGANIC SUBSTANCES IN THE SUGAR CRYSTAL IDENTIFIED

The color-bearing compounds within the raw sugar crystal have been classified into four groups:

1. Naturally-occurring plant pigments.
2. Thermally-degraded carbohydrate products.
3. Alkali-degraded carbohydrate products.
4. Molecular interaction products (melanoidins) of amino acids and the substances produced in 2 and 3.

The plant pigments have been identified as anthocyanins, of which cyanin predominated, catechins and chalcones.

The thermally- and alkali-degraded substances of carbohydrate origin are compounds containing carbonyl and enediol groups. They are similar to the thermal degradation products of fructose and to the alkaline degradation products of reducing sugars.

The products of interaction with amino acids, the melanoidins, have been identified by their electrophoretic behavior. They are not simple reaction products of amino acids and sugars.

In addition to these colored compounds, several polysaccharides have been isolated (Figure 39). These include dextran, starch, xylan and araban. Dextran probably has its source in cane juice as a product of the growth of microorganisms, a most

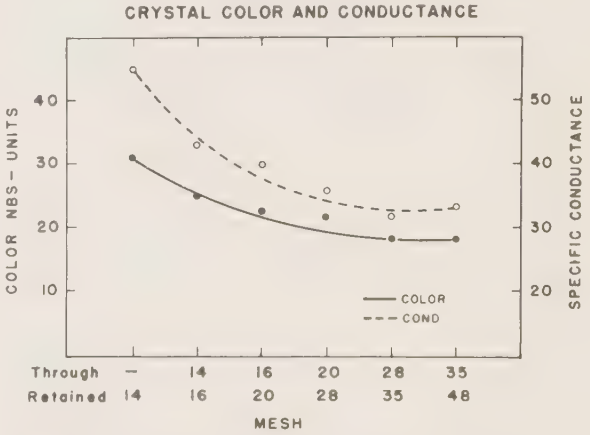

Figure 38. Color and ash (Conductance) change with the size of the raw sugar crystal.

common one being Leuconostoc mesenteroides. Starch has been isolated as a constituent of many varieties of cane. Xylan and araban are pentose polysaccharides having their origin in the fibrous structure of the cane. All of these polysaccharides are colloidal materials.

STARCH IN CANE SURVEYED

Starch, as a constituent of raw sugar, may adversely affect the refining quality, in particular filterability.

A survey of the starch content of cane by variety and location has shown that the presence of starch is a varietal, and not a locational, variable. No starch was found in eight samples of variety 37–1933 from various islands. Five samples of variety 49–5 showed no starch, while two samples showed a trace. All other common varieties contained starch, with 44–3098 and 39–7028 having the largest amounts.

Results of quantitative analyses were as follows:

Cane Variety	No. of Samples	Starch in Cane, %	
44–3098	8	0.063	
39–7028	4	0.042	By extraction and polarization
44–2772	1	0.027	
38–2915	2	0.009	
Natal Uba	1	0.010	
49–5	2	Trace	By microscopic examination
	5	None	
37–1933		None	

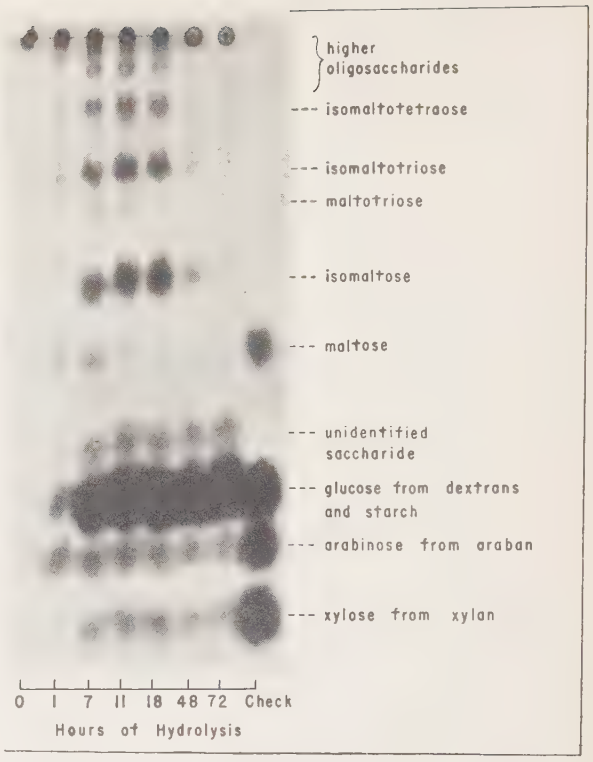

Figure 39. Chromatogram of hydrolysis products of polysaccharides in the raw sugar crystal.

VARIOUS SUBSTANCES AFFECT RATE OF CRYSTALLIZATION OF SUCROSE

Both glucose and fructose, principal reducing sugars present in cane juice, have an accelerating effect on the crystallization rate of sucrose. The effect of glucose is illustrated in Figure 40.

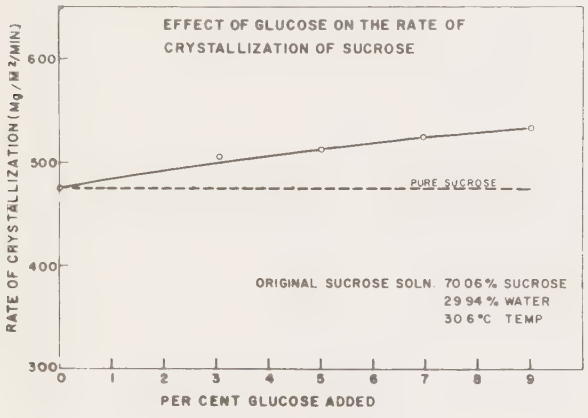

Figure 40.

This rate-increase effect is also evident in the presence of potassium chloride which slows down the crystallization rate. This is shown in Figure 41. Potassium chloride exerts a much greater influence than the sugars.

Two inorganic salts which have been used at

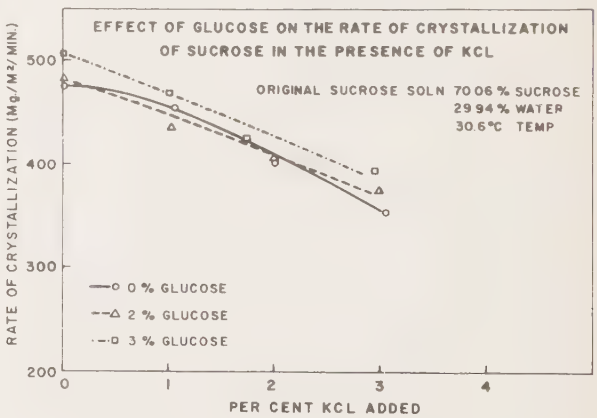

Figure 41.

various times in sugar processing have been found to increase the crystallization rate of sucrose substantially. These are sodium hydrosulfite and manganous sulfate. Sodium hydrosulfite at a concentration of 0.5 per cent increases the crystallization rate 15 per cent. Mangarous sulfate at the same concentration caused a rate increase of 22 per cent. Again, in the presence of potassium chloride also, a decreasing rate effect is predominant.

Sodium sulfite, on the other hand, diminishes the rate of crystallization of sucrose. This is of interest because of the wide use of sulfites in the beet sugar industry for bleaching.

ANION MEMBRANE PROBLEM IN ELECTRIC MEMBRANE DEMINERALIZATION STUDIED

Following the strike, the Ionics electric membrane demineralization pilot unit was put back on stream at HC & S Puunene factory. Studies were limited to the problem of buildup of electrical resistance of the anion membranes. Lightweight membranes of the strong base type backed with glass fabric have proved far superior to any membranes used heretofore. These have low initial resistance, and life tests still in progress indicate that they do not foul as rapidly as other membranes. Solution to the fouling problem thus appears to lie in the direction of thinner membranes. The cation membranes, in use for three years, show no deterioration.

SUGAR QUALITY TEST PROCEDURES ESTABLISHED

New test methods for appraising the refining characteristics of raw sugar were set up as routine during the year.

A new dry-screening test developed by California and Hawaiian Sugar Refining Corporation for the determination of small grain was investigated. As it was found to be much more satisfactory than the old wet-screening method, it has been adopted as the standard test method. The test is readily adaptable to factory use.

Methods of color analysis have received major attention. As a result, the Beckman Sugar Colorimeter is now in routine use for the determination of crystal color. It is expected to replace the old C & H Colorimeter.

For factory use, the less expensive Bausch and Lomb Spectronic 20 Colorimeter has been adapted. This instrument is very reliable and of sufficient accuracy for routine purposes.

FACTORY OPERATIONS FOR 1957

Sugar production for 1957 totaled 1,084,616 tons calculated as 96 D.A. value. This marked the sixth successive year that the million-ton mark has been passed.

Milling rates again increased, reaching an average of 85.7 tons net cane and 95.3 tons milled cane per hour. Milling performance, as measured by extraction and milling loss, improved slightly over the 1956 low.

Cane quality exceeded the 1956 level, but did not come up to the standard of the previous several years.

Processing-plant figures were characterized by few changes from previous years. Pol of commercial sugar of 97.75 was the highest since 1932. Sugar quality as indicated by grain size, crystal color, and filtration rate generally improved. Total pol recovery was slightly below recent year averages.

INSECTS

THE INSECT PICTURE FOR 1958

No change has occurred in the entomological picture of our plantations during 1958. Not a single call relative to insects was received by the Entomology Department from any plantation during the year, and no new developments were observed in the status of any of the established sugar-cane pests.

Anomala Beetle: This beetle has continued to spread slowly over a large part of Waialua plantation, but it can be found only with difficulty and is everywhere under the tight control of its efficient parasite, the scoliid wasp *Campsomeris marginella modesta.*

Sugar-cane Borer: *Rhabdoscelus obscurus* continues to be the only seriously harmful insect on sugar cane, but there have been neither reports nor evidence that its numbers or depredations have increased beyond the level complained of in 1956 and 1957. The work of the beetle, however, is a matter of concern to plantations which practice long cropping, and it would amply justify an effort to obtain a greater degree of control than can be attained in long-crop areas by *Microceromasia sphenophori*, the only parasite of the borer in Hawaii.

Armyworms: 1958 has been the fourth consecutive year of the complete absence of armyworms from cane fields. Only one species of armyworm, *Pseudaletia unipuncta* (Haworth) did build up to harmful numbers during the first half of the year on the paddocks of Kahua Ranch, Kohala district, and, during May and June, devastated about 500 acres of Kikuyu grass. Presumably the same species was also reported in somewhat less abundance from the ranges of Kukaiau Ranch, Hamakua district, and from pastures in the Kilauea region.

A study of the infestation on Kahua Ranch disclosed the absence of all but one parasite (the tachinid, *Eucelatoria armigera* (Coq.)) out of the long list which in former years was always associated with armyworms in the cane fields. This fact gave weight to the suggestion that an additional parasite, one practically specific to *Pseudaletia*, be introduced to Hawaii. Such a parasite, the braconid wasp *Apanteles militaris* (Walsh), is known to exercise strong control over *Pseudaletia* in the southern United States and can be reasonably expected to have the same effect here, if introduced. At our suggestion, the Territorial Board of Agriculture and Forestry has placed this introduction on its agenda.

Minor Pests: Only the sugar-cane leafroller, *Omiodes accepta* (Butler), received special attention, an abortive attempt having been made to establish a possible egg parasite for it in the cane fields of Oahu and Hawaii. The parasite, an encyrtid wasp of the genus *Litomastix*, is being introduced into Fiji and Samoa from New Guinea to combat the notorious banana scab moth. It is not known to attack any other host, but as the genus of the scab moth and *Omiodes*, the genus of our sugar-cane leafroller as well as of our coconut leafroller, are very closely related, it is reasonable to suspect that the species of both will prove susceptible to the same parasites. The suspicion, however, remains to be verified at some future time, for the single shipment of *Litomastix* which was sent to Hawaii from Fiji proved to contain only males, and females have not since become abundant enough for export.

MEALYBUGS GIVEN SPECIAL ATTENTION

J. W. Beardsley spent two and a half months at the National Museum, Washington, D. C., broadening his knowledge of the *Coccoidea*, the group of insects which comprises the mealybugs and scale insects. This work has already resulted in unprecedented advances in our knowledge of the *Coccoidea* of the Pacific region, and the clarification of an important problem of long standing in the Territory, that of the identity of the so-called pineapple mealybug, long associated with the transmission of pineapple wilt disease. It is now established beyond doubt that two mealybugs have been hiding for years in Hawaiian pineapples

under the identity of ore, *Pseudococcus brevipes* (Cockerell). This knowledge may explain the failure of past attempts to obtain biological control of the vector of pineapple wilt disease and, if followed by logical corollary action, may well lead to future control and economic benefit.

RAT CONTROL GIVEN MAJOR EMPHASIS

Work on the development and testing of new rodenticides has been resumed along new and promising lines involving the use of Endrin, a chlorinated hydrocarbon which has not been studied hitherto in relation to rats, but which has given good results on the Mainland in the control of mice and insects. From preliminary work in the laboratory, it appears that this chemical, when sprayed on the ground cover, will not kill rats in the field as it generally kills mice; but it does show useful characteristics as an internal poison at relatively high concentrations. These characteristics are that the material does not appear to be easily detected by rats, that it kills them quickly through their ingestion of very minute quantities of it, and that it is not soluble in water, which may well prove a significant advantage in the wet areas of many plantations. How the characteristics vary in relation to many potential carriers of the poison and in relation to each of the four species of rat in the Territory is being determined, but the process is necessarily slow and laborious. Up to now, it is apparent only that, at high concentrations, the poison is more deadly to females than to males of all species, and more deadly to *R. norwegicus* than to the other three species.

Since there are already available several good baits adapted to the customary pan-application of rodenticides, one of the main objectives of the department continues to be the development of a cheap and efficient bait to be broadcast by aircraft or land vehicle. Endrin shows promise among the various chemicals which might be used as the lethal component of this bait, and it appears to be particularly well adapted for use in combination with a new carrier which is also undergoing careful scrutiny.

This carrier is a milk dog-biscuit put out by the National Biscuit Company, and it is one of several dozen commercial pet foods which have been investigated. In limited laboratory and field trials, it has proved superior in its acceptance by our four species of rat to any other carrier in actual or potential use. To impregnate them with Endrin, the biscuits are soaked for a few minutes in acetone in which the poison has been dissolved. When so treated, they constitute a very quick-killing bait which is resistant to moisture, fungus and insects, and which is quite easy and safe to handle. Unfortunately, the biscuits cannot be used economically on a large scale in the shapes in which they are presently marketed; but there is assurance from the manufacturers that if a large enough demand for them can be developed, other shapes will be made available. The testing of new and old shapes is to be continued in combination with Endrin and other poisons, particularly 1080 (sodium fluoroacetate), in the hope of obtaining a number of alternative baits for a wide range of conditions.

Four field tests of thallous-sulphate-maize in prebait poisoning were conducted on the island of Hawaii during the year, and they showed that this combination can be used instead of the normally employed mixture of thallous sulphate and rolled oats. But the limited tests showed no clear-cut advantage for the use of maize in this manner, unless it is used as an alternative carrier in case rolled oats should become either unavailable or, in very dry weather, temporarily unattractive to rats.

Because of the strike and general lack of interest, no further tests of maize as a carrier for broadcast application have been made since those conducted at Lihue in 1956. It is proposed to promote this line of investigation again in 1959 in order to compare the relative advantages of maize and dog biscuit in combination with Endrin, 1080, and possibly other poisons better adapted to the method than the thallous sulphate tried at Lihue.

Considerable progress was made during the year in the unceasing campaign to increase interest and improve knowledge of rat problems and control procedures on the plantations. In this respect, the prolonged sugar strike afforded normally busy supervisors ample time for the consideration of the problem which was of great help to the Entomology Department. A series of educational lectures delivered on the various islands during the strike resulted in an unprecedented volume of calls from the plantations. Attention to these calls has required extended stays on the outer islands and, in many cases, strenuous participation in the field

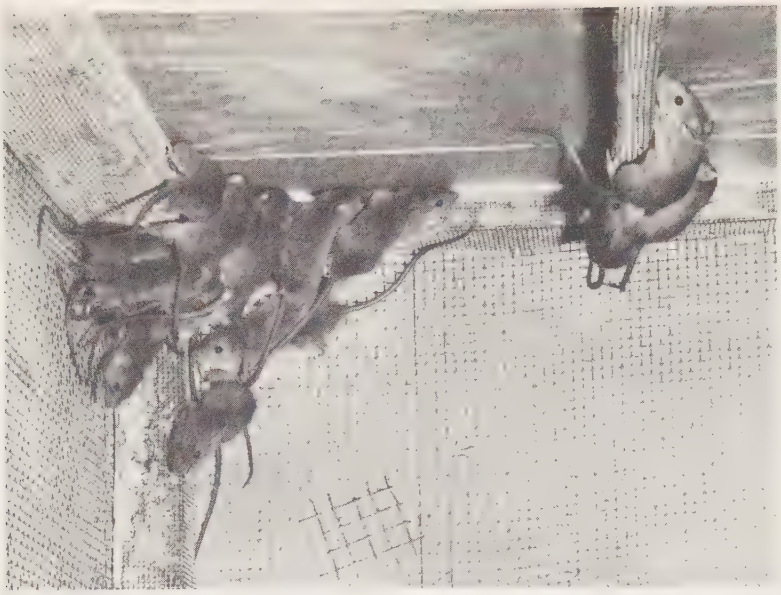

Figure 42. Progeny of one pair of Hawaiian rats, born during a three-month period.

work of the plantations; but the results are increasingly and gratifyingly apparent. The list of the plantations which have recently undertaken to improve their abatement programs, to drastically modify them, or to establish new programs, includes the following: on Oahu, Waialua, Kahuku Plantation Company, and Oahu Sugar; on Kauai, Lihue, Grove Farm Company, Ltd., and Kilauea Sugar Company, Ltd.; and on Hawaii, Hawaiian Agricultural Company, Hutchinson Sugar Company, Ltd., Olaa Sugar Company, Ltd., Hilo Sugar Company, Ltd., Laupahoehoe Sugar Company, Hamakua, Paauhau Sugar Company, Ltd., and Kohala Sugar Company.

Accumulation of data on the biology and ecology of our rodents has continued as an important project which, while it is never neglected, must be necessarily paced in accordance with demands made on the limited personnel by more pressing issues. Of particular interest in this connection has been the successful rearing of a large family of *Rattus hawaiiensis* from two adults which were captured together in January 1958. In September, the family was in the fifth generation, and threatened soon to overflow our premises (Figure 42). As this is the first time that the species has ever been reared under observation, the project is expected to result in much new information, all of it of scientific interest and much of it of economic value.

IRRIGATION

GROUND-WATER DEVELOPMENT FOR IRRIGATION

Early in 1957, Kekaha stopped construction on two Maui wells which produced six and eight mgd respectively, only about half what was hoped might be obtained. Some of the reasons for the low yield were:

1. greater length of tunnel in talus than anticipated.
2. a dike encountered in one of the wells.
3. plugging of the lava-flow porosity by clay near the water table in both wells, with extreme plugging in one.
4. an abnormally low water table due to heavy seasonal draft and low recharge.

Short drilled holes somewhat improved the performance of one of the wells and probably would have improved it more if they had been vertical.

Recommendations have been made by the Geophysics Department for converting the HC & S Maliko well, at which the last steam pump in the industry is located, to electricity. Tests have been outlined for the Paia mill well, at which a heavier yield is desired.

Individual drilled wells at Kahuku mill were isolated and capacity-tested as possible sources to meet an increased demand, but a coral-pit well was finally recommended for additional water.

EVAPORATION STUDIED WITH PANS AND LYSIMETERS

In the evapotranspiration project that is being conducted cooperatively by the HSPA and HC & S, the oldest cane is approaching harvest. The cane ages in the three fields equipped with lysimeters and weather instruments are: Field 205, 14 months; Field 405, 17 months; Field 906, 18 months. Throughout the experiment, records have been kept of evapotranspiration from lysimeters, pan evaporation, rainfall, sunshine, temperature, humidity, and wind. Atmometer evaporation has also been added. A running comparison has been kept not only of the evapotranspiration but the evapotranspiration to pan evaporation ratios, in which the climatic effects are supposed to be compensated, leaving variability ascribable to the stage of plant growth.

A plot of lysimeter to pan ratios by date would show a wide and meaningless scatter, because it would confuse the effects of growth stage with the experimental variability. In Figure 43, the average monthly lysimeter to pan ratios for the three fields are arranged by lysimeter consumption cumulated from planting date, on the grounds that the growth of the cane is proportional to the evapotranspiration. The early lysimeter evapotranspiration has been estimated on the basis of an assumed 0.4 ratio to pan evaporation. Missing pan data have been supplied by comparison with nearby standard pan installations. The data from lysimeter No. 5, in which the cane was hopelessly set back by CMU damage, have been omitted from the averages for Field 405.

It will be noted that with the growth of the cane, the evapotranspiration ratio rises from a bare-soil value of about 0.4 to a peak, when three or four

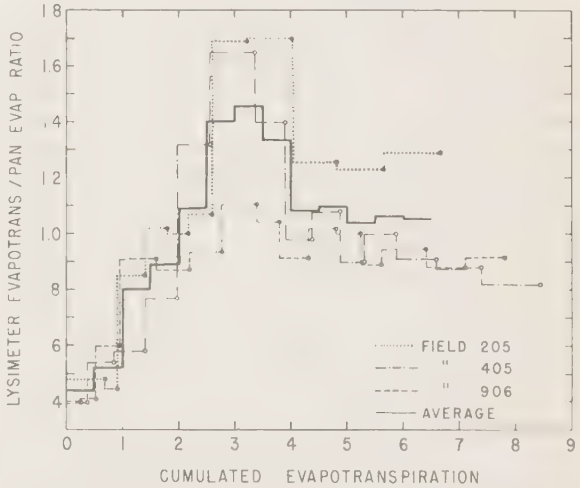

Figure 43. Evapotranspiration/evaporation ratios at HC&S plotted against cumulative evapotranspiration.

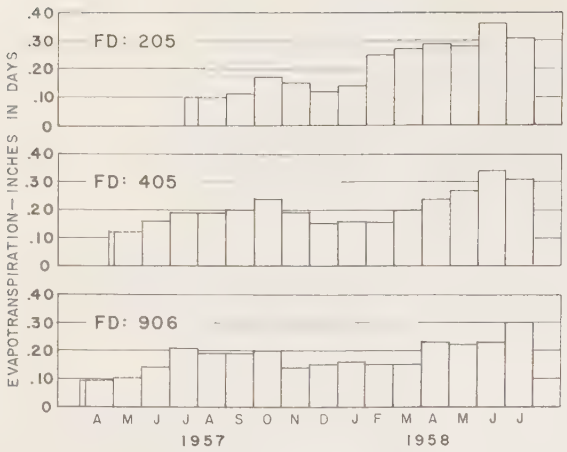

Figure 44. Evapotranspiration rates from three locations at HC&S.

feet of water have been used in total, and thereafter drops to a relatively stable equilibrium value. There is very good agreement in the rate of early increase in the ratio, but the magnitudes and timing of the peaks and the final equilibrium values do not agree so well. The differences in the magnitudes of the final values may well be due to observed experimental difficulties. The cane in the lysimeters in Field 205, in which the equilibrium ratio is about 1.3, has always done somewhat better, by visual observation, than that in the surrounding field. The cane in all of the lysimeters in Field 405 was set back by CMU damage and has always done more poorly, and that in Field 906 was so severely damaged by a storm at the end of November that the canopy has still not recovered complete continuity. The equilibrium ratios in these fields average about 0.9. The differences in the peaks are harder to account for satisfactorily. Some of the possible explanations tend to make the high values (about 1.7 maximum) seem more meaningful than the low values; others tend to suggest exactly the opposite. It is possible that the matter will be settled only by data from a second crop. Not much reliability can be ascribed to the averaged march of lysimeter to pan ratios until the variations are understood better.

LYSIMETERS PROVIDE FACTS ON WATER CONSUMPTION BY CANE

The data presented in Figure 44 show the water consumption from lysimeters in three areas at HC & S for the first year in a two-year crop cycle. The water consumption for approximately the first two months was estimated from pan evaporation data, using a factor of 0.4. The actual period of time during which the consumption was estimated is given by dotted line on the bar graph. The use of water was determined by averaging the use rate from three lysimeters in each of the locations, except in Field 405 where lysimeter #5 was omitted because of apparent weed spray damage to the plants earlier in the crop.

In Field 906, planted in late March, the crop reached peak water consumption by July. Weed spray damage in Field 405 is believed to have influenced results during the first season. A peak use period was not observed in Field 205 during the first season because of the late planting date. The winter use rates were about the same in all sites, and are in the order of 0.19 inch per day, indicating that irrigation practices should be carefully managed during this period. During the second season, the water use has at times exceeded 12 inches of water used in one month. Since these are the first data of this type obtained in Hawaii, they should be viewed with some reserve until more complete data are obtained from the ratoon crops.

The data as presented indicate a use of 70 to 90 inches of water per year. Comparing this figure with the actual water applied to the cane fields indicates that big gains in irrigation can be made by improving the application efficiency.

WEATHER INSTRUMENTS HELP STUDY EVAPOTRANSPIRATION

To meet the needs of the evapotranspiration project, a constant-level, continuous-recording evaporation pan has been developed that gives a record of evaporation with a tenfold magnification. The pan is essentially a standard Weather Bureau pan in which the water level is kept, by constant supply, at the level of an overflow in a central stilling well (Figure 45). The supply is pumped from a reservoir to which the overflow returns. The pump rate is somewhat in excess of the maximum evaporation rate, and the overflow rate is then the difference between the pump rate and the evaporation rate. During rains, the overflow rate exceeds the pump rate by the rainfall rate. The reservoir has an area one-tenth that of the pan, so that the water level changes in it, which are recorded by

an ordinary water-stage recorder, are 10 times as great as the changes that would occur in the pan if the reservoir system were not used. The fuel pumps initially used in the system have given trouble, and they are being replaced by small centrifugal pumps operated at higher rates for periodic short intervals. Otherwise, three of the pans have operated very satisfactorily over a period of nearly a year at HC & S. One pan is installed at the Pineapple Research Institute Waipio Field Station for comparison with a standard pan. Preliminary scanning of the comparative data indicates no essential differences in rates.

The Waipio Field Station is being used for testing a variety of sunshine and evaporation instruments in cooperation with the University of Hawaii and PRI. Besides the new HSPA pan, a University totalizing constant-level pan, a variety of Livingston and Bellani atmometers, two Gunn-Bellani radiation distillometers, and a blueprint sunshine recorder, have been installed for comparison with standard instrumentation.

Wind instrumentation is under particular scrutiny because of the requirements arising from testing of overhead irrigation. Good wind measuring equipment is available, but cheaper instrumentation is being sought. A new cheap vane has already been proved satisfactory for routine recording. Special wind instrumentation was designed, constructed by the Instrument Shop, and loaned to HC & S for use in sprinkler testing.

WATER CONSUMPTION BY CANE GIVEN CLOSE LOOK

Water-plant relationships are being studied with sugar-cane plants growing in covered metal containers which serve as miniature lysimeters. Accurate control and accounting of all water taken in by the plants is thus possible. Figure 46 shows a number of portable lysimeters, divided into groups which received different treatments. The data collected thus far show:

1. Plants which are never under moisture stress are far outgrowing those which are periodically subjected to moisture stress of varying intensity.

2. Growth as shown by spindle elongation proceeds at a uniform rate until, as the wilting point is approached, growth practically ceases, to be resumed at a normal rate very soon after water is applied.

Figure 45. HSPA constant-level, continuous-recording evaporation pan.

3. Weather factors, such as solar radiation, air temperature, humidity, and wind velocity, all affect, to some extent, the rate of transpiration. Wind velocity has been found to have very little effect on the rate of transpiration at the Makiki Station. Solar radiation, on the other hand, is by far the major factor, as shown by the high correlation illustrated in Figure 47.

Evaporation from a black spherical atmometer is largely influenced by solar radiation. The degree of correlation between transpiration and evaporation from a black spherical atmometer is therefore high, as is shown in Figure 48. This high degree of correlation makes the atmometer an instrument which should have value in the possible control of irrigation through the application of weather data.

EXPERIMENT "MASI" INSTALLED AT HC & S

An irrigation experiment was installed in August 1958 as a cooperative project by HC & S and the Agronomy and Field Engineering Departments of the Experiment Station, HSPA. Its purpose is to test methods of application (M), amount of water applied (A), surface shape and cover (S), and irrigation interval (I); hence MASI. The overhead irrigation equipment, designed by the Field Engineering Department, consists of a rotating boom infiltrometer, capable of applying water at rates of

Figure 46. A group of portable lysimeters in the early stages of cane growth. In the background are weather instruments and apparatus for measuring evaporation.

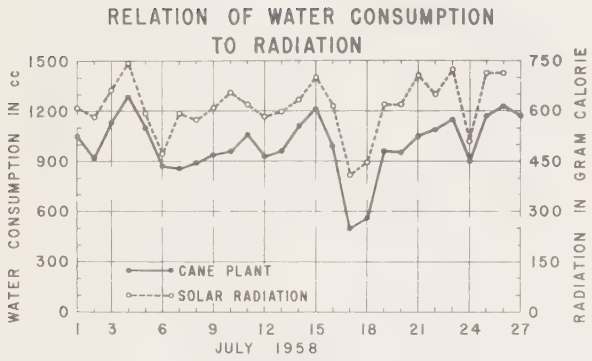

Figure 47.

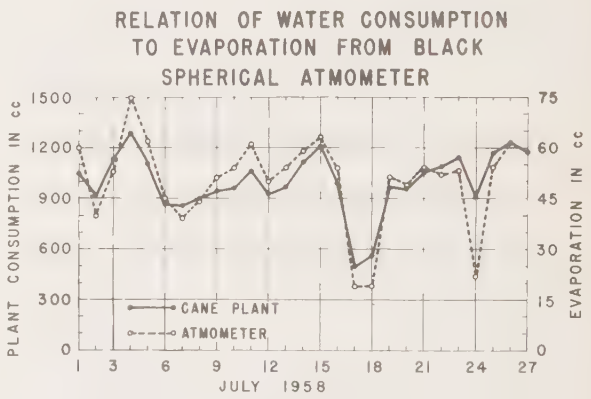

Figure 48.

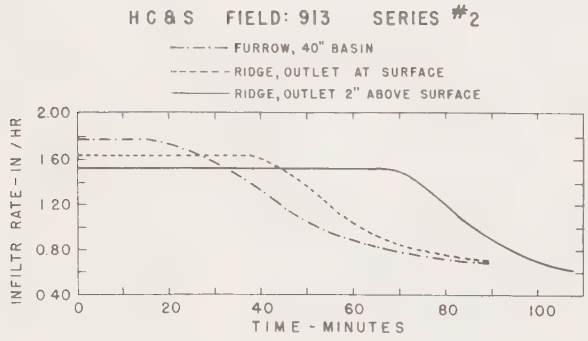

Figure 49. Characteristic infiltration curves show the water-holding capacity of various basin-listed surfaces.

0.5 to 4.0 inches per hour. The furrows are irrigated with gated aluminum pipe.

The experiment has the following specific objectives: (1) to determine soil infiltration rates in relation to age of crop; (2) to compare yields of cane grown under overhead and furrow-cropping systems; (3) to compare yields of cane grown in trash-covered and in bare surfaces under overhead irrigation; (4) to compare runoff from storms and from irrigation from two surface slopes; (5) to compare the yields of cane grown in four moisture regimes; and (6) to determine water storage capacity of soil and depth and rate of root extension in overhead and furrow layouts.

Table 10 gives more complete data for several surface shapes and surface covers. All plots were on zero slope.

Table 10
Time to Soak in 6″ Water

Surface Shape	Surface Cover	I	II
		(Min.)	(Min.)
Furrow	Bare	23	—
Furrow	Trash	19	29
Ridge	Bare	14	25
Ridge	Trash	12	19
Flat	Bare	11	16
Flat	Trash	11	14

The results shown cannot be applied generally to all soils because the infiltration properties of the soils are as varied as the general slope of the land. However, the data illustrate the potential of making use of ponds and surface cover in an overhead irrigation program.

Pulehu silty clay loam soil has a moderately low infiltration characteristic. The influence of the size and shape of the basin in relation to the period of application before runoff was tested in this soil. The first treatment consisted of a furrow eight inches deep, 16 inches wide, in which earth dams five inches high were made to form a basin 40 inches long. This basin-listed furrow overflowed in 16 minutes, when water was applied by an overhead boom applicator at the rate of 1.80 inches per hour. The boom spray made 24 passes per hour, giving 0.075 inch per pass. The same equipment was used to test the second and third treatments which consisted of a ridged surface with 5.0 feet between ridge centers, and 3.5 to 4.0 feet of reasonably level land between ridges. The ridges were made on contour and these tests were made on level land.

The only difference between the two treatments was that in the second treatment the outflow tube was placed at natural ground level, and in the third treatment the outflow tube was placed two inches above ground level. The ends of the plot were built up to exceed two inches, giving a basin-listed plot four feet wide at the bottom and 10 feet long.

The results are summarized in Figure 19. The point at which the curve falls off marks the time at which runoff started, and when runoff starts the infiltration rate curve begins to develop. All three treatments gave the same intake rate between 90 and 110 minutes. In an hour and one-half after the irrigation was started, the soil had soaked up 1.78, 1.91 and 2.15 inches in treatments one, two and three, respectively.

STUDYING FURROW IRRIGATION WITH NEW TECHNIQUES

The inflow-outflow method of evaluating the infiltration characteristics of furrows has been augmented by a method based on measurements of the rate at which water advances in a furrow. The accuracy of both of these methods depends on a known and constant inflow rate at the head of the furrow, but this is especially critical for the rate-of-advance method. Equipment has been assembled and tested which gives good control of both magnitude and constancy of inflow. This equipment consists of a lightweight gasoline-powered pump which discharges through a manifold with six outlets (Figure 50). The outlets are fitted with interchangeable orifice plates, and a special gate valve mounted on the pump provides control of the head in the manifold, permitting selection of flows from a few gallons per minute up to about 100 gpm for delivery to the furrows. This system can be substituted for small-size Parshall flumes which have been used to measure inflows.

The inflow-outflow method has been described in earlier reports. The rate-of-advance method is more elaborate. It determines the parameters which describe the normal decrease in infiltration rate with time. In principle, this could be done with the inflow-outflow method, but the analytical procedure is laborious, and it is customary to assume that the infiltration rate has reached a

Figure 50. Constant head flow measuring equipment: A sponge rubber ball serves as a cap for each orifice while water displaces the air from the manifold to a riser valve which circulates the water to the level ditch until the test begins. During the test, water is pumped from the level ditch in the background, through a flexible hose to an aluminum pipe manifold, six inches in diameter, and is discharged through orifice plates into six furrows. A gate valve mounted on the pump is used to control the height of the water column in a plastic riser. The depth of water in the riser indicates the pressure of water in the manifold system.

constant value at the time that the essential measurements are made. The rate-of-advance method has been set up to permit rapid computation of the results by IBM machine methods. It is anticipated that this method will reduce the labor of both collection and analysis of data. The results may be used to obtain estimates of the distribution of water which would be expected for conditions other than those prevailing during the field test—i.e., for different inflow rates, furrow lengths, and periods of irrigation.

ENGINEERS ATTACK VARIOUS PROBLEMS OF SURFACE IRRIGATION

Techniques for layout of level ditch fields with the objectives of increasing irrigator performance and improving layout for mechanical operations have been investigated by the Field Engineering and Agronomy Departments in cooperation with Kahuku. This work used minimum level ditch grades, adequate level ditch tubes, and an assumed allowable variability of furrow slope.

Another cooperative project in progress at HC & S and Lihue will help determine what can be accomplished in the improvement of irrigation and field layouts by means of land planing, degrees of grading, and a range of variability of furrow slopes. Since land planing can be done without hazard of yield decline, the layout improvement can be applied to the field (Figure 51). Optimum degrees of grading and furrow-slope variability for representative types of fields can be determined by means of surveys and board layouts as a basis for a next step.

Cooperative work is in progress on techniques for determination and elimination of ditch and reservoir losses. The installation of an asphalt membrane in a reservoir and ditch were observed at Oahu Sugar (Figure 52). Some determination

Figure 51. One of the two types of land planes introduced on Kahuku, HC&S and Lihue plantations as an aid to improving both field and irrigation layouts.

of ditch losses and investigations of lining materials were made at Kahuku.

Investigation and development of irrigation equipment is being resumed. The advantages of metal flumes warrant additional improvement to attract wider acceptance.

Data and information are being accumulated for a handbook covering the engineering aspects of surface irrigation in Hawaii.

INFILTRATION STUDIES IN RELATION TO OVERHEAD IRRIGATION

The maximum rate at which water can be applied to the soil by various types of overhead equipment continues to be a subject of interest. In general, the soils of the Hawaiian Islands are relatively permeable to water, particularly when water is applied in such a manner that the surface aggregates are not destroyed. The industry has large quantities of plant residues available in the form of trash and bagasse which could be used to protect the surface soil aggregates. These plant residues applied at the rate of approximately five tons per acre (dry weight basis) are sufficient to give good surface protection.

An example of the length of time required for the soil to absorb a six-inch layer of water is shown in Figures 53 to 56.

Figure 52. Hot asphalt membrane is applied on the surface of the reservoir at Oahu Sugar. (Cooperative project with Oahu Sugar, Jamor-Cooke, Ltd, and Douglas Oil Company.)

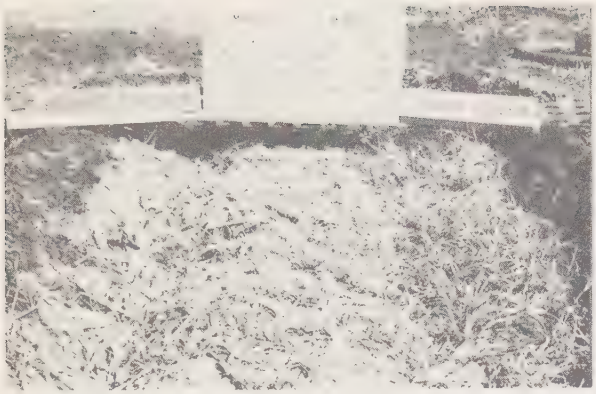

Figure 53.

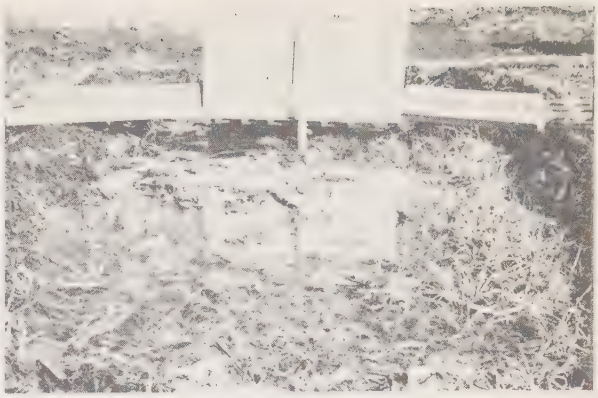

Figure 54.

Figure 55.

Figure 56.

Figure 53 shows a trash-covered surface ridged to make a basin four feet wide and 10 feet long. Water was pumped in at the rate of one and one-half inches in depth for four minutes, making a total of six inches applied. The ponded depth did not exceed two inches at any time during the application. Figure 54 shows the plot after six inches of water had been applied. Figure 55 shows the plot seven minutes after the application started. Figure 56 shows the plot after all the water had soaked into the ground. When the principle of surface cover combined with shallow ponding is utilized, water can be applied at higher rates for a short time.

ENGINEERING ASPECTS OF OVERHEAD IRRIGATION

A rotating boom sprinkler infiltrometer was designed, constructed, and tested for use in a field experiment in which the rate of application will range from one-half inch to four inches per hour. The over-all boom length is 100 feet. The water is discharged from holes in the lower side of the boom pipe (Figure 57). Tests have demonstrated that water can be distributed uniformly from a rotating boom with discharge pressure as low as 1½ psi and with negligible drift in winds up to 20 mph.

Investigation of different systems and equipment, based on economic potential, is under way to determine a starting point which can be recommended for project work. The semi-permanent system with laterals laid on top of the ground is attractive from the standpoints of equipment cost and irrigator labor. Small rotary sprinklers would be used and the recommended spacing of sprinklers would be in the 30-foot by 50-foot range. The distribution delivered by these smaller size sprinklers in winds above five mph are not available from the manufacturers. A series of tests has been completed in winds ranging up to 20 mph, using facilities at HC & S (Figure 58). These data assure

Figure 57. A rotary infiltrometer, with a diameter of 100 feet, is being tested cooperatively at HC&S. The rate of application can be varied from one-half inch to four inches per hour, and the perforated pipes can be raised as the cane grows.

Figure 58. This setup at HC&S determines the distribution of small-sized sprinklers in winds ranging from 5 to 20 mph, at heights from 1.8 feet to 13.8 feet above the gauges.

a satisfactory distribution layout for a locale where wind records are available. This type of system requires removal of sprinklers and laterals ahead of harvest burnoff. An effective procedure for this removal operation is not immediately apparent. The laterals and sprinklers would be reinstalled after harvest. Mechanical field equipment used in conjunction with such a system would have to be adapted to its requirements.

Food Machinery Corporation, Shur-Rane Division, is developing an automatic semi-permanent system which may result in further saving of operating labor and capital cost. The key development is an automatic valve at the base of each riser. One sprinkler operates consecutively on each lateral, which allows low water-flow rates and small lateral size. If Shur-Rane's tests and improvements continue to give good results, a 10-acre test in sugar cane is planned.

Another type of overhead irrigator, which has several attractive features, is a traveling boom sprinkler. Key problems are the economies of a minimum design unit and the economics of getting the water continuously to such a moving unit. Results with the rotary boom infiltrometer indicate that the maximum pressure would be little greater than that required to overcome frictional flow losses. Exploratory design of equipment and system is continuing. One of the good features of this type of system is a field layout which would facilitate all field operations.

The HSPA subsidized the fabrication of a rotary irrigation boom by the Pomona Irrigation Equipment Company. This was a continuation of some work which they had started several years ago in relation to a revolving boom which sprinkled a square pattern. The unit consists of a light revolving boom with an over-all length of 100 feet. A four-nozzle valve, located on each end of the boom, turns on and off so as to sprinkle the corners of the square. This cooperative study was aimed to demonstrate a low-cost unit, use of low pressure, uniform distribution over a square pattern, and the possibility that such a boom would sweep close to the cane. Preliminary operation at Pomona gave results that fell far short of the objectives. Because of the difficulties of continuing this project at Pomona, the equipment has been shipped to Honolulu for necessary testing and changing before conclusions can be drawn.

MECHANIZATION

HANDLING ORGANIC MATERIALS

A survey of commercially available equipment to spread cane cleaner trash in the field was made. This equipment is relatively low in first cost, but is of low capacity and light construction for cane field use, though it would be adequate for experimental use. Preliminary designs and cost estimates were made for three types of units which could be fabricated and developed for this operation.

The first design is a low-slung 12.5-ton capacity spreader-trailer mounted on two track assemblies, to be pulled and powered by a 75 hp tractor. A full dump-truck load would be dumped directly into the spreader which, it was estimated, would spread 2.8 tons per minute. This type of equipment could presumably cope with difficult field conditions.

The second design is a self-spreading truck body to be used in hauling cane trash and to spread its own load. It was estimated that such a truck would spread its load at the rate of 3.5 tons per minute.

The third design is a low-slung spreader attachment which would be hooked onto a dump truck while spreading its load and would then be left in the field. As the truck with attached spreader unit moved along, the load would be gradually dumped into the spreading unit and spread. It was estimated that this combination could spread 3.5 tons per minute.

MECHANIZING LIQUID FERTILIZER PRODUCTION

Laboratory tests by the Chemistry Department indicated the possibility of dissolving muriate of potash directly with aqua ammonia, producing a non-corrosive solution.

A pilot plant, set up at Oahu Sugar fertilizer plant, consists of a 100-gallon mixing tank, a 250-gallon aqua ammonia storage tank, and a 250-gallon storage tank for the potash-aqua-ammonia solution (Figure 59). The muriate of potash is placed in a tray in the upper portion of the mixing tank and the aqua ammonia is percolated through it. The aqua ammonia is circulated in a closed system by a centrifugal pump until the muriate is dissolved. No heat or mechanical mixing is used. The results compared favorably with other systems for obtaining potash-aqua-ammonia solutions.

The maximum mixing temperature depression is 20° F. A relief valve set for ½-ounce pressure

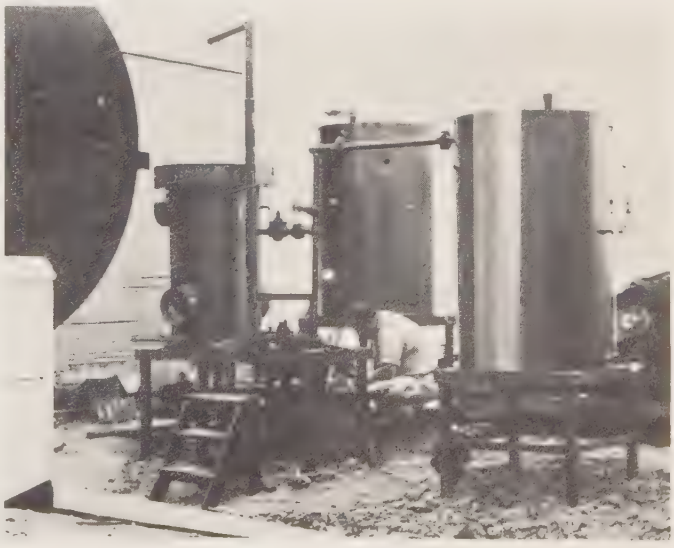

Figure 59. Pilot plant for mixing aqua ammonia and muriate of potash. The mixing tank is the smallest.

and ½-ounce vacuum is used on the mixing tank. Pressures developed during the mixing period are not enough to lift this relief valve. Being a closed system, this valve does lift when simples are pumped into the tank and when the finished concentrate is pumped out.

Length of mixing time varies with the concentration required and the size of pump used. Maximum dissolving time is 30 minutes. Minimum dissolving time is 15 minutes. Pump capacity in gallons per minute should be one-half to three-quarters of the volume of the mixing tank. The pump, centrifugal, all iron, can be a low head pump. Ten psi at the nozzle outlet is required.

Using aqua ammonia and muriate of potash as simples, the maximum concentration obtained in this apparatus was 17.5–0–7.12. The maximum amount of muriate of potash that dissolved in water in this apparatus was 0–0–14.2. The maximum K_2O and N obtained in a muriate of potash, aqua ammonia and water solution, was 10.4–0–10.0. Other concentrations obtained were 7.52–0–12.0, 7.71–0–11.75, 7.62–0–9.14, and 6.87–0–11.62.

These tests were run with bagged regular muriate of potash containing 61 per cent K_2O. Tests are now being run with bagged granular muriate of potash containing 60 per cent K_2O. Aqua ammonia containing 20 per cent N is used for all the tests.

SEED CANE HARVESTER UNDERGOES FIELD TRIALS AT KOHALA

A machine to cut one row of flat-culture erect seed cane was designed and constructed. The cane is cut off at the ground after the stalks have been engaged by gathering chains and topped. The tops are dropped off continuously to the outside and onto the ground. The stalks are conveyed continuously in the erect position through three high-speed, small-tooth saws, spaced 18 inches apart, which cut the stalks into seedpiece lengths. As the cut cane is conveyed into a bulk seed bin carried on the machine, the flow is subjected to two air blasts which do an effective job of detrashing. The prime mover is a 60-inch gauge D6 tractor.

Field testing was started at Kohala in October 1957 (Figure 60). Initial operation showed that the principle and design were sound as long as the assumed cane and field conditions existed. Considerable development has been aimed principally at maintaining quality work over a greater range of conditions, and at attaining continuous operation. Daily production has ranged up to 23 tons in an eight-hour shift using bins with a capacity of 1000 pounds. The major changes made so far are: 1) design and installation of a new topper assembly to reduce backfeeding, wrapping, top recutting, and power consumption; 2) extension of gathering chains to improve pickup of lodged cane; 3) addition of shields and cleaner plates to reduce wrapping on hubs and shafts; 4) revision of bin rack to reduce bin-changing time and allow use of three types of bins; 5) installation of a second blower assembly doubling the volume of air discharged from both blowers, and revision of the deflectors to increase detrashing; and 6) addition of deflectors between corrugated feeder belts to reduce leaf trash backfeeding.

A preliminary study made by the Station's Industrial Engineer was favorable. The condition of the seed, though acceptable, left room for improvement. The quality of work falls off as the percentage of lodged cane increases, because the stalks which are not brought up to an erect position by the gathering chains are poorly topped and pass through the saws at various angles. Observation comparing the germination of machine-cut and hand-cut seed indicated no difference.

When the machine is cutting adequately erect cane, the cutting rate is approximately 20 tons per hour. Some exploratory design and planning have been aimed at attaining more continuous cutting so as to give better production. New approaches which have been explored are: 1) two-bin capacity rack, 2) two-bin rack with self-unload, 3) towed trailer for carrying two to four bins, 4) use of a truck for carrying bins while being filled, and 5) storage bin or storage conveyor as part of machine. Industrial Engineering analysis indicated the desirability of installing larger capacity bins and making it easier to handle them. It was estimated that by using a large bin (154 cubic feet) with an efficient handling system, the potential production would be 45 to 50 tons per eight-hour shift.

MECHANICALLY HARVESTING LODGED CANE FOR SEED

A cutting assembly aimed at tolerating more lodged cane has been designed and fabricated. The stalks are cut off at the ground after being engaged

Figure 60. Seed cane harvester in operation at Kohala. Note vertical arrangement of the cutting assembly.

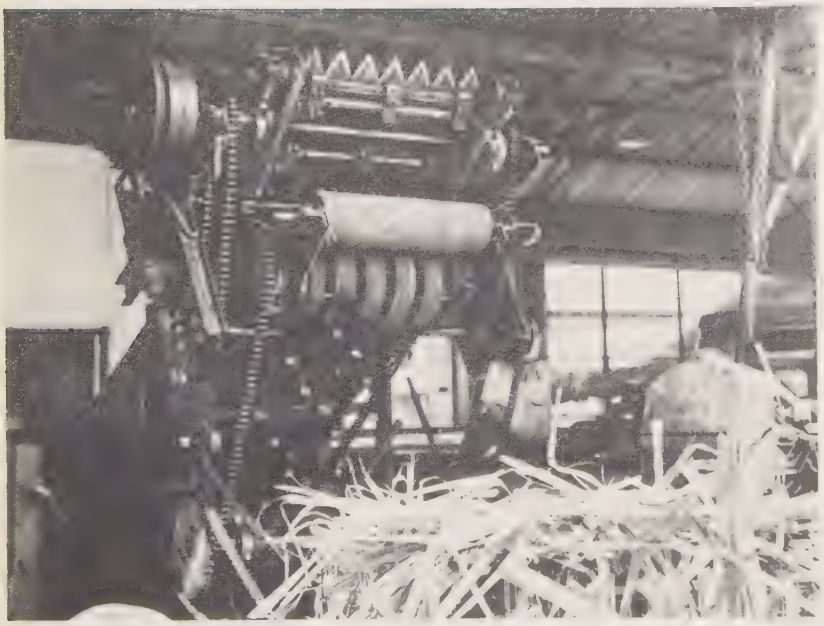

Figure 61. Assembly designed and fabricated to test the feasibility of cutting a flow of seed cane with a cross-flow type of cutter.

by gathering chains and topped, the tops dropping off continuously to the ground. The stalks are then laid down continuously in a conveyor 24 inches wide and cut into 18-inch seedpiece lengths by means of a cross-flow type of cutter (Figure 61). It is expected that cane lodged with the row will feed into the conveyor either top or butt first. Two blasts of air are retained for detrashing.

Laboratory results were favorable for a cutter assembly which did not keep the knife assemblies in a vertical position as a means of simplifying the cross-flow cutter design. Results confirmed calculations for tip diameter and rpm of the knife assembly, showed that sickle-bar speed could be as slow as 400 cycles per minute, that the blade angle should be perpendicular to the average depth of cane flow, and that complete backing is required for the cane as it is being cut.

The arrangement of this assembly lends itself to reasonable first and maintenance costs, weight and weight distribution, and adaptability to cutting in furrows. It will replace the present cutting assembly for field testing. The prime mover, loading conveyor, and bin rack will be used without change.

HANDLING HARVESTER-CUT SEED

It was estimated that an optimum bin capacity for the seed harvester was one ton. The seed density of 13 pounds per cubic foot set the volume at 154 cubic feet. The dimensions were set at 11 feet eight inches long by three feet eight inches wide by three feet eight inches deep. Present bins in the industry range in volume from approximately 75 to 108 cubic feet.

It was suggested that an attractive saving in cost of a bin of this size would be possible if no side gate was required for emptying the bin into the planter. A forklift attachment was devised which would dump a bin through an angle of 128° thereby pouring the seed out of the top.

Two bins of the above dimensions were designed, one with a gate and one without. The bin with gate weighed 806 pounds, and the gateless bin weighed 712 pounds.

Everything was favorable for the gateless bin and the extra forklift cost for dump through 128°, except that the costs of materials and fabrication of the two types of bins were approximately equal. The gated bin had the advantage of the use of side hooks for picking up. A forklift attachment for tipping the gated bin 30° was designed.

LILIKO PICKUP—A MAJOR PROBLEM

The 10-foot-wide star-wheel liliko-pickup unit has been in operation on an experimental and semi-production basis which has led to several changes in the support and stripping of the pickup wheels, and in the elevating conveyor. The changes to the pickup wheel assemblies were required to eliminate occasional clogging by accumulations of small stalk pieces and leaf trash. A boot was added to the bottom of the elevating conveyor to eliminate losses as the conveyor received the cane from the pickup wheel stripper plates. The overhang of the conveyor over the near side of the hopper was increased two feet, and flexible material was added to the slats to eliminate backfeeding. The volume of the hopper was increased to accommodate up to 2000 pounds of cane.

The initial test was made in dry conditions and the results were very encouraging (Figure 62). Approximately 95 per cent of the liliko was picked up following pushrake operation by running the machine over the area twice. Also, direction of travel was not important. The machine could pick up one acre per hour, including the two passes.

However, wet conditions proved to be another problem, as sticky soil as well as cane was picked up (Figure 63). This picked-up soil caused trouble in the stripper and conveyor; some of it was frequently mixed with the cane in the hopper. Some progress has been made for operation in friable soils by adding scrapers, increasing the clearance between cane strippers and pickup wheels, and spraying the periphery of the pickup wheels with Teflon. Results so far indicate that this principle of pickup is not practical for sticky soil conditions.

A front or third wheel was added, thus eliminating the weight carried on the tractor drawbar, and increasing the ease of operation substantially. A second unit is in use, owned by HC & S.

A LILIKO CUT-WINDROW MACHINE FOR ATTACHED CANE

Under some cutting conditions, most of the liliko is left attached to the stools in a semi-erect position. A light unit aimed at cutting and picking up

Figure 62. Liliko pickup, operated under dry conditions, shows the flexibility of individually mounted pickup wheels.

Figure 63. Liliko pickup, operated under wet conditions, shows the action of the pickup wheels.

this liliko has undergone its initial field tests. The prime mover is a small track-type tractor which was widened from 42 inches to 72 inches by moving the right-hand track assembly 30 inches. The engine was moved six and one-half inches toward the left-hand track assembly. The cut-pickup-conveying assembly, which is located along one side of the engine between track assemblies, consists of a pair of gathering tines, a rotary ground-cutting knife, and two sticker chains for conveying. The elevated cane is dropped into a conveyor-unload hopper on the rear.

Initial field testing showed that the principle of gathering, cutting and elevating had possibilities. However, the optimum location of the gathering tines, ground knife, and sticker chains, had not been attained on the initial design. The ease of adjustment of all subassemblies became important in order to operate experimentally with the three basic elements in different relative positions. Essentials include some means of gauging cutting height more effectively and of coping with rocks that feed into the throat.

In order to revert to a step-by-step procedure, the gathering and conveying assembly and the hopper were removed, leaving the ground-knife assembly. The gauge wheel was relocated directly ahead of the knife. This arrangement is operating satisfactorily as a liliko cutter-only (Figure 64). The liliko pickup machine is being tried as a complementary operation. The development of the combination unit will proceed as soon as necessary design changes are made on the gathering-conveying assembly.

CUT-WINDROW (SIDE-MOUNTED) MACHINE IMPROVED

A total of nine cut-windrow machines of the side-mounted type have been in operation in both irrigated and unirrigated cane for from two to

Figure 64. With the gathering-elevating assembly and the storage bin removed, the liliko cut-windrow machine is shown operating with the ground-knife assembly as a liliko cutter-only.

eight years. Since this is a one-way machine, cutting can usually be into the general lay of the cane for easier pickup. The results have generally ranged from very good to very poor, a range largely the result of field conditions, state of development of principles and mechanisms, supervision, maintenance, adjustments, and the training and skill of the operators. The greatest problem has been the gradual accumulation of soil and leaf trash on the deck of the elevating conveyor under wet, sticky conditions. By cutting too high, the operator can keep the deck cleaner when unfavorable conditions exist, but high cutting is the major cause of liliko. A number of ideas, including putting Teflon on the deck, have been considered and tried, with only limited success. A recent observation at Laupahoehoe indicates that a camber in the deck may make a major improvement. This, combined with a short moving deck over the ground knife, may be an answer for many unfavorable conditions.

The several changes made on the HSPA-owned cut-pickup-elevating conveyor assembly are: 1) adding three pickup tines; 2) shortening by six inches the two pickup tines which straddle the line being cut; 3) changing the side-trimming knife to a free-cutting knife driven from the end of the pickup roll; 4) shortening the left-side pickup chain and driving it from the other end of the pickup roll; 5) mounting a powered, lightweight drum-type reel to float over the pickup; 6) installing a moving deck over the ground knife; and 7) locating the gauge wheels in the furrow back of the ground knife.

These changes are aimed at increasing cutter efficiency and reducing liliko.

Hamakua had a new elevating-conveyor assembly fabricated to replace an assembly which went into operation in April 1950. A complete machine of this type was fabricated by a Honolulu shop for Hacienda Cartavio. This is the second machine purchased by Hacienda Cartavio.

CUTTER-TRANSPORT—AN IMPROVED DESIGN

Three cutter-transports have given good results in unirrigated cane under a wide range of weather and terrain conditions. Revision of the original design revealed that increasing costs had priced this machine out of business. Also, maintenance costs of existing machines had been high. A review of the problem suggested the possibility of a less custom-made prime mover, simplified drives, and reduction of weight throughout. The design and drawings of such a machine are nearing comple-

Figure 65. The two-way cut-load harvester operating at Ewa.

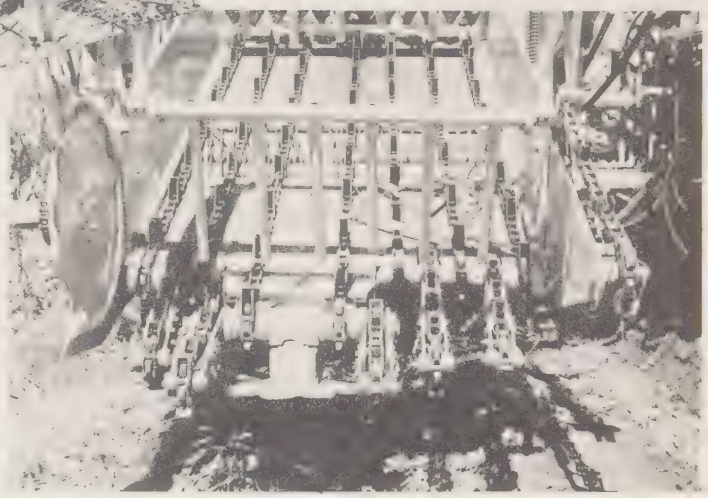

Figure 66. Experimental cut-pick-up assembly of the two-way cut-load harvester is equipped with a free cutting side-trim knife, extra pickup tines, pickup reel, and Olsen-type rolls in the deck.

tion. Preliminary estimates indicated that the total weight could be reduced to about 17.5 tons, with a decrease in production costs. With complete drawings, more reliable estimates of weight and cost can be made.

A 74-inch gauge D6, with turbocharged engine (140 hp at 1800 rpm), seven-roller track frame, and 30-inch track shoes, is used for the prime mover. The right-hand track is moved out two feet four inches to give a gauge of eight and one-half feet. The elevating conveyor, ground knife, and cross-conveyor will be driven by individual oil motors, eliminating all countershafts. The only chain drives are from the outer end of the pickup roll shaft to the free-cutting side-trim knife, and from the inner end of the pickup roll shaft to the pickup reel. The oil pumps will be driven by the front power take-off of the engine. The structural design has been revised to be lighter and cheaper. The three-inch conveyor chains have been retained.

TWO-WAY CUT-LOAD HARVESTER MAKES INITIAL FIELD RUNS

After initial operation of the two-way cut-load harvester in late 1956 and early 1957, two objectives were set up, 1) to attain minimum tare delivered to the transport, and 2) to leave negligible liliko on the field. The establishment of an adequate production potential was considered a second phase at that time. After studying several detrashing principles by means of exploratory designs, a peg-tooth-drum blower assembly which could be installed in a cross-load conveyor was selected as a first step toward substantial detrashing. As reported in 1957, several additional alterations were made.

Space limitations kept the detrashing principle from functioning as effectively as it had in the field cleaner. Testing showed that at least two times as much drop from the drum to the load conveyor was required. Since to provide adequate

drop for the cane at this point would require substantial changes to the machine, some of which would introduce new problems, the principle was abandoned.

In late 1957, the development procedure was reviewed, at which time the value of showing its potential production was recognized. The objectives for the near future were revised to 1) attain second gear (2.18 mph) cutting speed as standard, 2) leave negligible liliko, 3) introduce detrashing features when possible, and 4) continue reduction of machine weight and cost, while increasing mechanical efficiency (Figures 65 and 66).

Cutting speed and liliko are closely related phases of the development. The semi-automatic features, furrow-follow by cut-pickup assembly and cutting-height gauging, appear to be key problems. Major changes aimed at solving this problem are, 1) eliminating the fulcrum shift mechanism which connected the elevating conveyors and mounting each conveyor with separate controls, and 2) mounting a bogie of four Terratires under each conveyor for gauging. Changes aimed directly at liliko reduction were, 1) adding three adjustable pickup tines to each pickup assembly, 2) synchronizing machine component speeds to 2.18 mph travel speed, and 3) using a combination chain and belt conveyor for loading. A set of three Olsen-type rolls were added to each elevating conveyor for desoiling and detrashing. There had been mechanical trouble with the cross-flow cutter rotation drive and the cutter bars. These were revised. Some of the changes contributing to weight and cost reductions are 1) reducing the number of hydraulic valves from 25 to 11, and 2) reducing hydraulic cylinders from 16 to eight. Equipment removed and assemblies replaced reduced the weight of the machine by about two and a half tons.

Limited operation in young cane gave favorable results for all changes. However, limited operation in heavy-tonnage harvest cane resulted favorably for everything except the semi-automatic features, that is, the mounting of the conveyors and the gauge wheeling for furrow-follow and height gauging. When the conveyor control cylinders were on float, the cut-pickup assembly tended to drift to the outside and to nose in. When the assembly was on the line with correct cutting height, the cutting and pickup were perfection. This is a key problem which will apply to any furrow-follow type of machine since experience has always indicated that the control of the machine by the operator is usually not sufficient for quality work.

A preliminary design has been completed to lower the conveyor pivot point from under the headshaft, six feet above the furrow, to one foot above the furrow. The conveyor weight would be balanced on the pivot point except for a light load on the gauge wheels. The swing of the conveyor would be retained for furrow follow, and the ground knife would be relocated at the center of the conveyor to equalize frontal resistance.

If work on this machine is continued, a tentative plan is to remount one conveyor assembly as described, add a blast of air and a deflector at the discharge end of the load conveyor for additional detrashing, and double the amount of cutting of cane on one conveyor in order to study the effect on detrashing and load density.

WEIGHING EXPERIMENTAL CANE

The Genetics Department pointed out the acute need of weighing cane in the grab while it is being loaded into a transport.

After reviewing the types of equipment available, a hydraulic remote-reading scale was procured from Martin-Decker and installed on the Waipio Substation hydraulic grab (Figure 67). The load cell was inserted between the end of the lift line and the grab, and the dial was located in the cab. The unit has a maximum capacity of 6000 pounds, with 10-pound graduations and a maximum tare adjustment of 1500 pounds. This size was selected in order to tare out the 1400-pound grab weight. This equipment is represented as having a maximum error of ± one-quarter per cent.

Initial testing showed that the dial reading changed when the height of the loaded grab was changed. The hydraulic line was so easily stretched that it also affected the dial reading. Initial field operation showed excessive weight errors even though an effort was made to read the weight at a uniform grab height.

Indications are that the major causes of error are, 1) the differences of hydrostatic head in the hydraulic line with different grab heights and boom angles, and 2) flexing and stretching of the

Figure 67. The Martin - Decker hydraulic remote-reading weighing device is shown mounted on the Waipio Substation's hydraulic grab.

hydraulic line by the slack take-up. Changes are planned to remove these sources of error before further testing.

LEVEL DITCH BACKFILL ASSISTS CANE HARVESTERS

When crossing level ditches, a cane cutter usually heels down, holding the cut-pickup high on the leeward side and leaving cane uncut. As a means of partially filling level ditches ahead of cutter operation, two six-foot grader blades were mounted in an inverted "V" on the rear of a pushrake tractor (Figure 68).

Field operation has shown that such a unit could be used to eliminate liliko along level ditches. However, combining it with a pushrake may not be entirely successful. The equipment is being strengthened and remounted for better control. Teflon sprayed on the blades has given good scouring.

METAL FLUME PICKUP FOR IRRIGATED FIELDS

The lightweight, track-type flume pickup was originally designed to straddle a flume and spread the lodged cane off the flume by means of a nose assembly. The flume could be disjointed and stacked in the rack on each side of the pickup, and outlets, crossties, etc., were loaded into the bin on the rear. Improvements are being made during the field testing of a new nose assembly which will complete the development of this phase (Figure 69).

This unit also proved a convenient means of transporting and distributing metal flume in a

Figure 68. Two six-foot adjustable grader-blades are mounted on the rear of the rake tractor for partially filling level ditches ahead of the cutter operation at Lihue.

Figure 69. With the use of the flume pickup machine, cane is cleared off the flume line, and metal flumes are picked up.

plant or ratoon field. An attachment to notch the ridges for the flume was suggested as a means of reducing hand work. A small furrowing-out type of plow was tried, but the soil deposited in the furrow had to be removed by hand. Later, a finned cone, rotated in either direction by an oil motor, was mounted under the tractor. Indications are that this device will do an effective job and the development is being completed.

With this addition, the unit has become an all-round transport for installing and removing metal flume.

PICKUP-TRANSPORT PROJECT ENDED

The design of the experimental pickup-transport was revised by C. Brewer and plantation engineers on the basis of cooperative field operation and testing. A new machine of the revised design is in operation at Pepeekeo Sugar Company. Pepeekeo also purchased the experimental machine from the HSPA.

TESTING HORSEPOWER USAGE

More reliability in the determination of draft and horsepower requirements is assured with a continuous recording over a period of operation. The development of strain gauge equipment in recent years has made this procedure possible.

An Offner portable, two-channel, type P Dynograph recording assembly and auxiliary equipment have been procured and will be used for draft testing with the moldboard plow project. The auxiliary equipment includes two pressure cells for recording hydraulic pressure.

A staff member who is specializing in the use of this equipment will work with project engineers in the determination of drafts, horsepower consumption, and stresses and strains.

PUSHING BACK CANE MECHANICALLY

A project was set up to develop a means for pushing cane back mechanically with results comparable to hand work. In addition to being effective, the assembly should be lightweight and flexible so that it could be used in different ways and be mounted on a light prime mover.

The designed and fabricated assembly is a powered corrugated belt, six inches wide, set at a 60° angle to the direction of travel with its speed so synchronized to travel speed that it pushes the cane over in the desired direction. The attachment to the prime mover and control allow the assembly to be operated at different heights and to be folded for travel.

ORGANIC CHEMISTRY

CHEMICAL WORK ON CANE WAX COMPLETED

The crude brown cane wax recovered from the floating scums of the mill cleaners is completely decolorized by passing a hot solution of the wax in a light petroleum solvent, such as commercial heptane, through a column of activated carbon. The yield is 75 to 80 per cent of a white wax, m.p. 78°C. Analytical determinations and spectrometric investigation show that free fatty acids, or other acidic degradation products, are the principal components removed by the carbon and are responsible for the color of the crude wax.

The decolorized wax has been shown to be composed of wax alcohols, ketones, esters and hydrocarbons. The unusual ketone fraction was separated by oxidizing the alcohols of a saponified portion to acids, and removing the acids as insoluble salts, leaving a pale yellow ketone, m.p. 77°C. Analysis gave a formula of $C_{76}H_{150}O_3$ and is a ketoacid or ketoester, probably the latter.

Commercial development of the waxes from the cane cleaner effluent is dependent on the economics of recovery of the wax which constitutes about two per cent of the dry weight of the wash water scums. This phase is currently under study.

CANE WAX EMULSIONS PREPARED

Testing of cane wax samples for several possible applications required the preparation of emulsions of the wax in water. Unmodified cane wax is inherently difficult to emulsify, which is one reason why commercial cane wax has been partially oxidized.

A satisfactory method was developed here in which a small amount (10 per cent) of the total wax dissolved in a hot solvent was sulfated with concentrated sulfuric acid and the resulting solution was neutralized with sodium hydroxide to form the sodium salt. This oil-soluble emulsifying agent (with or without the original solvent) was then blended into molten wax to be emulsified. The hot liquid was poured in a slow stream into a rapidly agitated aqueous phase containing hot water and a water-soluble emulsifier. The creamy emulsion did not separate on cooling and contained five per cent wax solids. The wax deposited as a white powder coating when applied to a surface. This could be rubbed to a gloss; or, alternately, methyl stearate at one-third of the weight of the wax was added to the oil phase before emulsifying. This emulsion, when spread on a surface, dried to a glossy waxy finish.

BAGASSE AND CANE TRASH COMPOSTING EVALUATED

Composts made from bagasse and cane trash were prepared, analyzed and tested as planting media for cane fuzz and seedpieces.

Decomposition of the fibrous material, mixed with about one per cent soil, fertilizer nutrients (about eight pounds per ton of fiber) and water, was essentially complete in five months with good aeration.

Analysis:	pH	N (%)	P_2O_5 (%)	K (%)	C (%)	H (%)	Ash (%)
Bagasse Compost...	7.18	0.24	0.47	0.34	4.07	1.59	81.74
Bagasse and Trash..	7.20	0.32	0.49	0.47	5.90	1.67	78.05
Trash Compost.....	6.97	0.31	0.47	0.50	5.36	1.58	79.92

The low carbon content is evidence that most of the organic material was lost as carbon dioxide, and the low fertilizer nutrient values make them doubtful media for planting materials. It appears that little beneficial chemical effect could result from incorporation of bagasse or trash into the soil; any value that results will be a rather short-lived physical change in the soil characteristics and in its water-holding capacity. Incorporation of filter muds would have the advantage of adding lime salts.

The bagasse and trash composts prepared were satisfactory media for cane fuzz germination, except that: 1) levels of N, P and K were inadequate for good seedling growth, and 2) seedlings were highly chlorotic. These deficiencies responded dramatically to treatment with fertilizer nutrients

and chelated iron, respectively. Neither effect was noted in pot germination studies of single-eye seedpieces. The chlorosis produced by iron deficiency was traced to the soil from which the compost was originally prepared and was not produced by the composting process.

Trace Analysis	Elements (ppm)						
	Fe	Mn	Cu	B	Al	Fe/Mn	Al/Fe
Makiki Germinating Soil	550	650	33	3.5	1625	0.8	6.0
Bagasse Compost	50	400	14	3.5	1150	0.1	46.0

AMMONIATED BAGASSE PITH PRELIMINARY STUDIES COMPLETED

In cooperation with the Animal Science Department, University of Hawaii Agricultural Experiment Station, feeding trials were conducted on young dairy heifers in which a balanced feed mix containing 30 per cent ammoniated bagasse pith (calculated so as to supply one-third of the total nitrogenous feed component) was compared to a feed mix containing urea nitrogen at one-third of the total nitrogen, and to a control feed mix in which all the nitrogen was present as true plant and animal protein. The feed mixes were prepared, consistent with previous work of this Station and the University of Hawaii, containing high levels of molasses as a carbohydrate source. Ruminant animal feeds can contain a maximum of about one-third of the total nitrogen in the form of non-proteinaceous supplement. Feeds containing 50 per cent ammoniated bagasse pith were unpalatable. Daily weight gains of all animals in the test were adequate, no toxic symptoms were found, and all three rations were palatable. The nitrogen in the ammoniated bagasse pith was utilized as well (60 per cent) as that in urea-containing feeds, but the fiber of the ammoniated pith was not adequately utilized. Taking into consideration the cost of the nitrogenous portion of the three feed mixes required to produce a pound of animal live weight, the check ration with natural protein was cheapest; urea and ammoniated bagasse pith rations were about equal to each other, but more feed was required to produce a unit gain and the cost of both was above the check.

The utilization of sugar by-products, especially molasses, for animal feeds has increased tremendously over the past 10 years. The local molasses producers have shared in the growth of the western United States cattle industry to supply the expanding western market with quality meat. There is evidence, too, that the use of molasses and other by-products of the sugar and pineapple industries in the Territory is expanding. A large measure of credit is due to the cooperative work carried out in past years by this Experiment Station and the University of Hawaii Agricultural Experiment Station on the use of feed mixes with molasses content of 60 per cent or more as the carbohydrate source. Much of this pioneering work is being reconfirmed on the Mainland where molasses has, up to now, constituted less than 30 per cent of the total feed.

The range and pasture production of beef cattle has long been an important industry in the Territory. It is encouraging now to note the increase in facilities for pen feeding and fattening supplementation, aimed at producing quality meat for the military, tourist and resident markets, and in providing adequate year-round supplies of feeds for dairy herds and for beef cattle where ranges are inadequate or seasonal. In addition to molasses, clean, chopped trash is finding an increasing market for roughage. Several installations on Kauai and Oahu are ensiling this material with a small quantity of added molasses, to be used year-round as required.

Molasses and bagasse-pith mixtures, as well as locally-produced alfalfa and pineapple by-products, will be utilized in the new Hawaii Meat Company installation being constructed at Iroquois Point, Oahu, and at Oahu Sugar.

BAGASSE COMPOSITION BOARD TO BE FURTHER INVESTIGATED

Composition board, ranging in density from commercial hardboards to insulation board, can be produced by combining dry bagasse or bagasse pith with five to 10 per cent by weight of diisocyanate, a class of organic chemical intermediates relatively new to the commercial market. The combination is formed in a press at moderate temperatures and pressures and in very short curing cycles. This provides an entirely new approach to binding of cellulosic fibers, since the diisocyanate combines chemically with the bagasse, forming a strongly cohesive structure. Its outstanding characteristics are: 1) that boards can be formed of bagasse pith alone where most processes must at

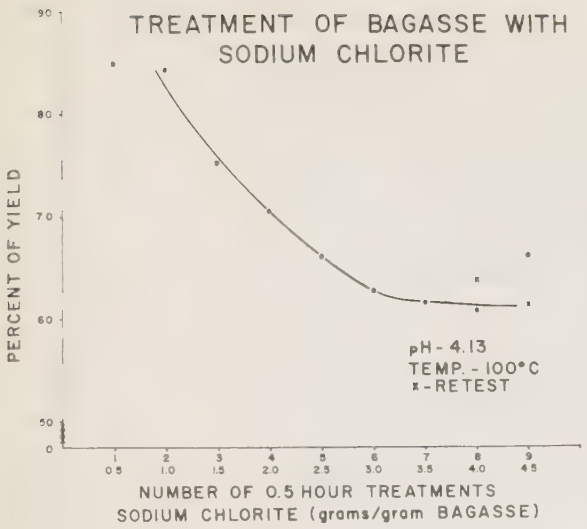

Figure 70.

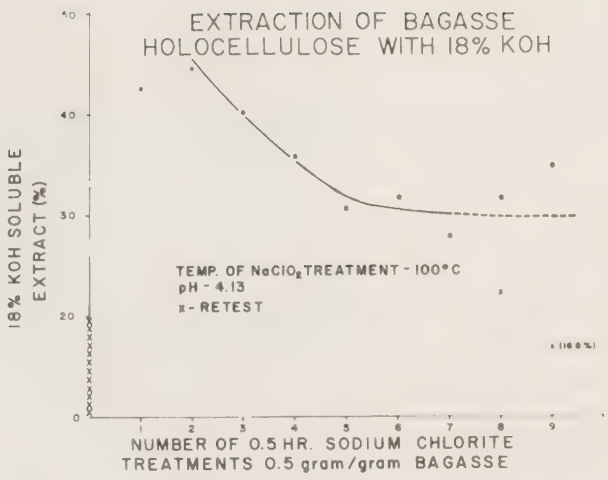

Figure 71.

least partially depith the bagasse; 2) that it has excellent water resistance; and 3) that it resists rotting when buried in wet soil. Application has been made and accepted for a patent with the U. S. Patent Office.

NEW SUGAR-BASED EMULSIFYING AGENT, PLASTIC AND WAX

In connection with the work on bagasse, the reactive isocyanates and diisocyanates are of potential interest in forming combinations with sugar. The properties of the new compositions depend on the kind and amount of isocyanate used to react with the sugar.

Toluene diisocyanate (TDI) reacts in one proportion (4 sugar to 1 TDI, by weight) in a non-aqueous medium to give a sirupy water-soluble product that is highly surface active and which has been used experimentally by the Chemistry Department of this Station as the emulsifier to produce stable standard herbicide CADE and ARCADE emulsions.

At a second concentration of the TDI (2 sugar to 1 TDI, by weight), a viscous solution is produced having polymeric characteristics. This is not water soluble but is water sensitive, and can be modified to make insensitive coatings and films.

Octadecyl isocyanate, another member of this class of intermediate, reacts with sugar to form water-soluble soapy waxes or solvent-soluble hard brittle waxes as the ratio of the isocyanate to sugar is increased.

Application for a U. S. patent has been submitted.

ANALYSIS OF BAGASSE FIBER FOR ALPHA-CELLULOSE CONTENT BEGUN

Preliminary investigation of bagasse fiber for cellulose content and properties has produced an exceptionally pure white sample of alphacellulose which will be used for further investigation of this important constituent.

Bagasse fibrous material treated with an acidified solution of sodium chlorite results in a white holocellulose, a mat of very fine fibers composed only of cellulose and pentosan (hemicellulose) and free of lignin. Figure 70 shows that about 37 per cent of the bagasse is dissolved out as lignin and other solubles. The latter are composed of residual sugar, soluble salts, gums and other water-soluble hemicelluloses, and comprise about 10 per cent of the bagasse.

Extraction of the holocellulose with 18 per cent caustic potash solution (Figure 71) removed all the hemicellulose, leaving 43 per cent of the original bagasse as alpha-cellulose and 20 per cent by difference as hemicellulose.

TILLAGE

MOLDBOARD PLOW MAKES SUCCESSFUL DEBUT

Experimental use of Teflon as a cover material for a moldboard plow as an aid to scouring, set off an investigation of its possibilities. The disc plow had become a standard in Hawaii because it generally gave better results in non-scouring soils. The Agronomy Department had emphasized the possibility of using a moldboard plow which might make possible better trash covering, lighter draft, better penetration, lower first cost, lower operating cost, and the better maneuverability of a direct-mounted plow.

The design of an experimental plow by the Department of Field Engineering incorporated a truss frame type of construction, easily removable parts, and a high degree of interchangeability of parts. The plow consisted of three 32-inch bottoms with an over-all width of cut of 96 inches (Figure 72). Each bottom assembly has a shear bar breakaway feature for protection against rock damage. The throat clearance permitted an average plowing depth of 18 inches.

Initially, one moldboard was covered with a one-eighth-inch Teflon sheet and the other two were sprayed with Teflon enamel. The plow was mounted on an 80-drawbar-horsepower tractor and was first operated in pineapple fields. The plowing conditions were excellent and most of the operation was made at an 18-inch depth and a travel speed up to two miles per hour. When the unit was shifted to heavier soils, the draft increased substantially. One-eighth of an inch of Teflon was added to the landsides, shares and a second moldboard, and improved performance and quality of work resulted.

For flexibility of testing, a larger tractor was needed. The plow assembly was removed from the 80-drawbar-horsepower tractor and mounted on a 148-drawbar-horsepower tractor, and has since been used on tractors of 162- and 135-drawbar-horsepower. Approximately 100 acres have been

Figure 72. The three-bottom, direct-mounted moldboard plow is shown with sheet Teflon on all shares and two moldboards, and sprayed Teflon on one moldboard.

Figure 73. A typical view of a two-inch surface blanket of trash buried by the HSPA's experimental moldboard plow.

plowed with this unit as a three-bottom plow, and approximately 190 acres as a two-bottom plow. Plowing speeds have ranged from one and one-half miles per hour to three miles per hour. Plowing depths have ranged from 16 to 24 inches. The plow has operated in soil types ranging from low humic to humic latosols, with moisture ranging from 20 to 38 per cent.

Production rates have not been established. Indications are that with a given horsepower, production is about 50 per cent greater than with a standard disc plow, with a comparable reduction in costs. However, continued progress in the economic use of anti-adhesive materials for scouring is essential.

The potential of Teflon as an anti-adhesive material is being determined. The Teflon sheet presents three major problems; cost, wear resistance and cold flow. The sprayed Teflon enamel has the advantage of very low first cost and the possibility of being practical. However, the high rate of wear has not been encouraging. The enamel shows most promise for soil-engaging parts under low pressure applications and where resistance to corrosion is essential. The reprocessed Teflon sheet has shown most promise as a means of reducing the cost and increasing the resistance to wear. Other similar materials are being investigated as to rate of wear, cost and practicability.

A subsoil point was added to the center bottom to subsoil 12 inches below the depth of plowing. The limited operation with this attachment was evaluated by the Agronomy Department.

Cooperative work with Oahu Sugar will be concerned with scouring materials and methods of application to the moldboard, shares, and landsides of their plow. It will also serve as a means of continuing this work under irrigated conditions. The plow will be reinstalled on the 80-horsepower tractor so that field tests can be started on unirrigated cane land.

A key requirement in evaluating different types of materials and different forms of any one material is a method for measuring draft. Steps are being taken to meet this need by the use of a two-channel recording strain-gauge unit. The initial test will be made on the unit operating on unirrigated land.

SOIL PHYSICS ASPECTS OF MOLDBOARD PLOW ACTION

Inversion of the soil within the tilled horizon has raised some speculation as to possible problems accompanying tillage with moldboard plows. Plantations have had ample experience with the "lift and sift" action of the subsoilers and with the "mixing" action of disc plows, but the practice of inverting the soil, which leaves subsoil exposed on the surface, has raised some questions. Indications from the soil conditions thus far encountered

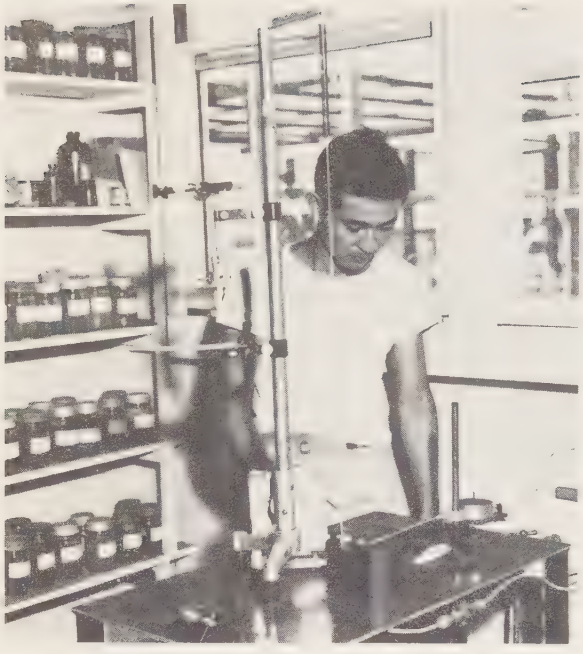

Figure 74. This apparatus is used at the Experiment Station, HSPA, for the determination of the adhesive force of soils.

lead one to believe that this type of tillage action will not present any additional problems.

The suggested burial of surface-applied trash and bagasse by moldboard plowing is being investigated. The size of the "pockets" of trash within the profile suggest unfavorable agronomic reactions with the development of the following crop, although the relationship to the crop has not yet been fully ascertained (Figure 73). Various combinations and sequences of additional operations to incorporate the trash more successfully within the tilled profile are also under consideration.

Some of the soils being tilled with moldboard plows are not developing adequate secondary shear. The rough surface condition which contains many primary shear blocks following tillage of some soils has presented some problems. Additional operations and various sequences of operations are being investigated to obtain an adequately smooth field in order that the survey crews can stake the guide furrows accurately. Deep tillage, with the accompanying lateral movement of soil during tillage, has also caused some problems with the placement and refill of the dead furrows. Methods of accomplishing this with a minimum of recompaction and effort are under investigation.

The apparatus illustrated in Figure 74 has been developed at the Experiment Station to test the adhesive properties of our soils under various soil moisture conditions and various contact pressures. Since the moldboard plow program depends upon the practical application of a coating to the plow which will reduce soil adherence, this apparatus has been utilized in an attempt to locate a material with adhesive tendencies similar to Teflon's, but with better wearability and dimensional stability. Figure 75 shows the relation of some of the ad-

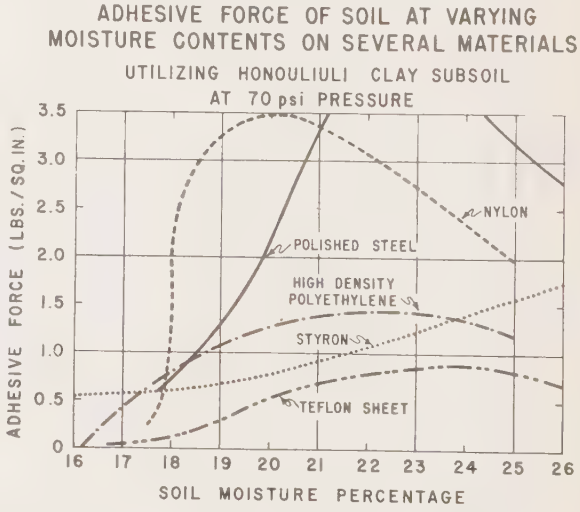

Figure 75.

Figure 76. The dynamic properties of soils are observed through a glass window when soils are being compressed under varying amounts of pressure.

hesive properties of some of the materials tested. Adhesion is only one phase of the laboratory test program developed at the Station to eliminate the undesirable products and thus speed up field testing with materials which offer more promise of success. Compressibility trials of test materials are conducted as an estimate of cold flow deformation. It is anticipated that, in the near future, laboratory wearability trials will be conducted jointly by the Agronomy and Field Engineering Departments.

SOIL COMPACTION BY INFIELD TRUCKS

Soil compaction caused by newly-initiated, infield truck harvest methods at Lihue is under observation. The Kenworth truck adapted with trailers, manufactured by Hilo Equipment Company, carries about 30 tons of cane with a 20-ton unit. The front cab wheels are equipped with 13.00 x 25 tires which carry about 75 psi air inflation while the remaining wheels are equipped with 16.00 x 21 tires at about 60 psi. The front and rear cab tires have a mean surface ground contact pressure of about 95 psi, while the trailer tires have a mean surface ground contact pressure of about 100 psi. Under these conditions, the main infield roadways in the makai fields did not become deeply compacted even during the summer rains. Table 11 may be considered indicative of compaction caused by loaded cane trucks during a summer rain in a Kahana silty clay soil at Lihue.

Table 11
Density–Moisture Relations in Field 31 Lihue Kahana Silty Clay.

	Main Roadway		Untrafficked Area	
Depth	Moisture	Volume Wt.	Moisture	Volume Wt.
In.	%	Lbs./Cu. Ft.	%	Lbs./Cu. Ft.
0–2	31.5	83.0	39.1	67.4
3–5	32.7	76.1	40.3	73.6
6–8	35.2	69.9	39.3	68.6
9–11	35.3	66.8	36.6	66.8
12–14	33.5	70.2	35.2	73.6
15–17	34.7	73.2	29.2	76.1
18–20	31.9	76.9	27.1	77.4

To understand better the roles of tread design and rim width on soil compaction, a laboratory analysis was made on new tires to eliminate the effects of tire wear and soil-bearing strength. In this study, it was found that the mean surface ground pressure can be affected by different tread designs: with the tire sizes and tread designs tested, the mean surface ground pressure can be altered by as much as 16 per cent. The effect of tire inflation can vary the mean surface ground pressure by as much as 30 per cent; and, although it is not evident in field studies, load can affect the mean surface ground pressure by as much as 17 per cent. In these studies, the effect of rim width was inconsistent: this effect produced a variation of the mean surface ground pressure of as much as four per cent, which was sometimes in a direct relationship, but usually in an indirect trend.

Figure 77. A typical view of the very compact soil cone formed beneath a piston. Notice the slickened sides in the area of soil movement.

WATCHING COMPACTION THROUGH A GLASS WINDOW

To improve the understanding of the dynamic factors involved in soil under pressure, metal bins have been constructed in which a glass window can be inserted so that pressure distribution and soil movement can be observed directly. Figure 76 is representative of the observations that were made in a recent study on a low humic latosol. Thin strips of wet tissue paper were placed against the soil so that its movement would be evident in the photograph. The strength of these thin strips is so negligible that they do not affect soil movement during observations. Figure 77 shows the cone of soil which had been trapped under a metal piston, being forced into a soil. Wedges of soil are formed ahead of a rectangular piston, instead of the cones formed ahead of the circular piston. These wedges and cones are very densely compacted, much more so than the compacted "bulb" of soil surrounding the wedge or cone. The formation of the wedges and cones and their effect on the movement of soil are being studied to determine which placement of pressure-measuring units in the field will lead to a better understanding of the degree and depth of compaction by vehicles and of the effort expended by field implements during tillage and cultivation operations.

VARIETIES

THE 1957–1958 CROSSING SEASON

The crossing season began on November 18, 1957, and ended on January 17, 1958 (Table 12). Hurricane "Nina" and several other periods of high winds caused damage to tassels in the crossing racks and in the breeding plots. This resulted in a 10 per cent reduction in the crossing program in comparison with the previous season which was unusually favorable.

Increased emphasis was placed on the Q.R. melting pot, recombining parents of exceptional juice quality. The number of crosses in this melting pot was almost double that of the previous season.

Table 12
Number of Crosses Undertaken During 1957–58 Crossing Season

General melting pot crosses	2,382
Leeward melting pot crosses	438
Windward makai melting pot crosses	326
Windward mauka melting pot crosses	223
Q.R. melting pot crosses	179
Bi-parental crosses	513
Field crosses	81
Total	4,442

PRELIMINARY TESTING AT THE REGIONAL STATIONS

The regional station network continued to operate at capacity during 1958. Some of the plantations are also conducting preliminary selection trials in problem areas not adequately represented by any of the regional stations.

The details of the preliminary selection programs are shown in Table 13.

Arrangements are being made to replace a 23-acre field at Kailua, which lies in the path of a housing development, with additional areas at Maunawili, Lihue, Helemano, Hamakua and Hilo.

NEED FOR SCREENING LARGER NUMBERS UNDER LONG-CROPPING

In harvesting yield trials, slash-cutting is much more efficient than cut-and-pull from the standpoint of man-day performance. However, since slash-cutting demands a minimum of two guard lines along either flank, it requires larger plots than were needed for cut-and-pull harvesting. When the regional stations operated on a 30x30 cut-and-pull basis, the harvested area amounted to 900 square feet per plot. The change to slash-cutting of 40x40's entailed an increase in gross plot size to 1600 square feet, but the discarding of guard lines reduces the net area harvested for yield to 800 square feet per plot. As plot size increases, the number of seedlings that can be accommodated within a given area decreases correspondingly. The regional stations are too limited in area to carry an adequate number of seedlings through a two-year crop in 40x40 plots.

If those seedlings which were most outstanding in appearance, vigor and Brix tally at a year of age, also proved to be the most outstanding in sugar yield at two years, the problem could easily be solved. By more rigorous selection at 12 months, the population to be tested under two-year cropping could safely be reduced to the smaller number that can be accommodated at the regional stations in 40x40 plots. Unfortunately, the correlation between ratings at 12 months and sugar yield at 24 months is not high enough to warrant such rigorous elimination. 37–1933, for example, rarely rates better than an equal at 12 months, but when harvested at 24 months, it has repeatedly outyielded canes which at 12 months had received plus ratings.

Such experiences point to the hazards of selecting too rigorously on the basis of 12-month ratings. In order to improve the chances of identifying canes that can outyield the present standard varieties under two-year cropping, it becomes necessary to evaluate larger populations at two years.

Under a given budget, the number of seedlings evaluated can be increased only by reducing per plot costs. It was this objective that led to the

Table 13
Plantings Made in 1958 at Regional Stations

Regional Stations	** No. of Flats	Number of Seedling Plots: Unnumbered 5′x3′	Numbered 5′x3′	5′x10′	10′x20′	20′x20′	30′x30′ and 40′x40′
Kailua Field Laboratory	2,334	4,024	316	...	...	...	...
Waipio Substation	1,569	14,120	2,722	956	...	246	...
Helemano Variety Station	...	2,665	1,313	851	...	...	...
Hilo Variety Station	275	5,131	2,186	968	82	10	17
Hilo Mauka Var. Sta.	587	5,552	661	1,147	87	...	...
Hamakua Makai Var. Sta.	384	3,540	1,493	874	65	8	20
Hamakua Mauka Var. Sta.	329	2,901	703	1,118	53	...	22
Kohala Variety Station	230	3,545	632	850	50	...	16
Kau Variety Station	25	5,302	1,620	976	149	...	18
Lihue Variety Station	586	6,054	3,230	399	68	24	16
McBryde Variety Station	302	5,595	1,332	1,618	...	164	...
H. C. & S. Co.*	...	2,824	3,081	781(1)	...	...	...
1958 Total	6,621	61,253	19,289	10,538	554	452	109
1957 Total	6,921	54,589	27,716	11,199	592	719	126

* H. C. & S. Co. 10x20 and 40x40 plantings tabulated in Table 3.
** Number of seedlings per flat = 100–1000.
(1) Includes 103 (5x20) plots.

Omitted from table:
(a) Breeding and spreading canes at Kailua Field Laboratory.
(b) Field Nurseries under special conditions.
Kohala Sugar Company—200 flats.
(c) Unnumbered 5x3 plots under special conditions.
Kohala Sugar Company—1,034 plots.
(d) Numbered 5x4 plots under special conditions.
Paauhau Sugar Co. —1,045 plots
Honokaa Sugar Co. — 979 plots.
Kohala Sugar Co. —1,068 plots.
Hutchinson Sugar Co.—1,021 plots.
Hawaiian Agr. Co. — 265 plots.
(e) 5x7 plots under special conditions.
Hutchinson Sugar Co.— 33 plots.
Hawaiian Agr. Co. — 40 plots.
Kohala Sugar Co. — 123 plots.

exploring of 20x20 plots, the interior two lines of which were to be harvested on a modified cut-and-pull basis. Harvesting experience during the past year has shown that this procedure is not feasible for heavy tonnages, particularly when the burn is poor. It was found at Waipio and Helemano, for example, that in spite of all precautions, the percentage of mixtures found in a two-line plot guarded by only one line on each flank is unduly high.

This experience has necessitated replacing the 20x20 stage with a compromise plot of six lines, each 16 feet long, plus an eight-foot cross path—a 30x24-foot plot, the two interior lines of which will be harvested on a straight slash-cut basis. At present, 30x24 appears to be the minimum that can be handled on a straight slash-cutting basis with adequate flank guarding. Such plots will, of course, have to be separated on a cut-and-pull basis along the eight-foot cross paths.

Hand cutting has become a major bottleneck in testing under two-year cropping. The 30x24 plot requires the hand-cutting of only 48 feet of line as compared with 160 feet of line in 40x40's. It should thus be possible to harvest about three times as many 30x24 plots with the labor that would be needed to harvest a given number of 40x40 plots when the four center lines of the latter are slash-cut for yield data.

The proportion of failures at harvest is unduly high under the present procedure of testing, in 40x40 trials, canes which appear promising at 12 months but which have not yet been evaluated for carry-over ability under two-year cropping. It should be possible to improve the average by restricting the more costly 40x40 stage to seedlings which have first qualified in the less costly 30x24 stage.

Under such a program, the regional stations would be devoted primarily to the 12-month screening stages, i. e., bunch, 5x3's and 5x15's. In addition, each station would test as many seed-

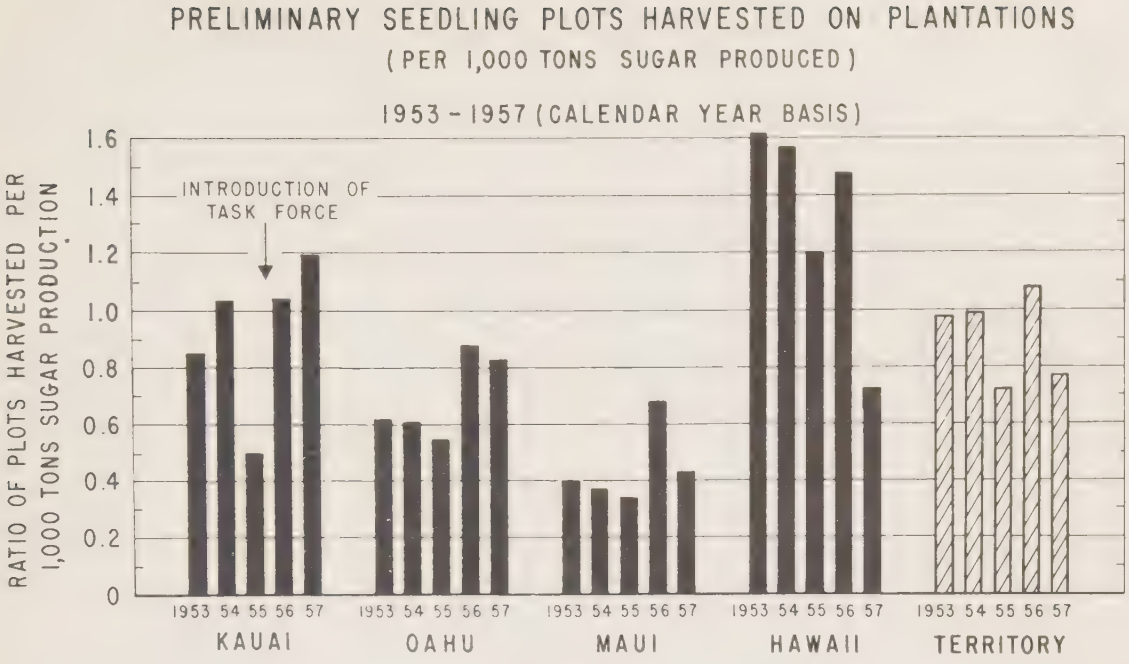

Figure 78.

lings under two-year cropping in 30x24 plots as the available area can accommodate. At best, the regional stations would be able to test in 30x24's only a portion of the seedlings which, on the basis of 12-month performance in 5x15's, appear to merit two-year testing. It is hoped that neighboring plantations will accommodate the overflow in plantation 30x24 trials.

The proposed revision of the testing program should afford several advantages.

1. The number of seedlings evaluated under two-year cropping would be doubled or tripled while keeping per plot costs to a minimum.

2. Preliminary screening in 30x24 plots should lead to a reduction in the number of canes in plantation 40x40 trials and an improvement in the proportion of successes.

We believe that these revisions of the testing program will increase the chances of identifying canes that can outyield the present standard varieties.

VARIETY TESTING ON THE PLANTATIONS

A breeding and testing program represents a long-term investment. The standard varieties that are being grown today must be credited to the expenditures of five, 10 and 20 years ago.

Plantation participation in variety testing still operates on a voluntary, pay-your-own-way basis with no assigned quotas. Under these circumstances, it is perhaps inevitable that the cost-price squeeze should reflect itself in a curtailment of variety testing, along with all other curtailable items. The recent decline of what has long been an exceptionally strong testing program on the island of Hawaii illustrates the problem (Figure 78). This graph terminates with the 1957 calendar year; it does not include the 1958 strike period.

With increasing pressures for reductions in operating costs, a curtailment of variety testing becomes more tempting. It offers the appeal of an immediate saving without jeopardizing this year's, or even next year's returns. Indeed, the damage thus incurred may not become apparent until replacements are needed for a standard variety that has begun to decline in yield.

A study by the Genetics Department of various means by which the testing program on the plantations might be strengthened to meet the yield decline threat indicates that one of the first steps should be the establishment of HSPA task forces on Maui and Hawaii like those now operating on Oahu and Kauai. The following benefits would be obtained industry-wide:

1. Testing would be more uniformly distributed over the cane-growing area.

2. The gradual development of skills by the task force would result in improved accuracy at lower cost.

3. The disruptive effects of seedling testing upon routine plantation operations would be eased.

Unreliable or misleading yield data can be costly. In variety testing, accuracy and economy go hand in hand. The task force approach offers possibilities for improved accuracy and efficiency in installing and harvesting variety tests. As an economy measure it merits careful consideration.

TESTS INSTALLED DURING 1957–1958 FISCAL YEAR

Table 14 shows the distribution, by island, of the preliminary tests installed during the fiscal year ending June 30. The drastic reduction in all categories may be attributed in part to the strike. It is hoped that intensified efforts during the remainder of 1958 may succeed in recovering some of the lost ground.

DISTRIBUTION OF SEED

In addition to their preliminary testing functions, the regional variety stations serve as seed propagating and distributing centers. Seedlings which show promise in preliminary tests at the regional stations are spread in seed nurseries for distribution to the plantations for further testing. Details of seed distribution are shown in Table 15.

Table 14
Number of Preliminary Tests Installed by Plantations—1957–1958
(Fiscal year ending June 30)

Type of Test	Kauai	Oahu	Maui	Hawaii	1958 Total	1957 Total
10x15 and 10x20	15	11	4	21	51	73
30x30 and 40x40	12	5	2	14	33	99

CYTOLOGICAL INVESTIGATIONS

Dr. Sam Price spent the 1957–1958 tasseling season in Hawaii during which period he collected material for a further study of the cytology of hybrids between wild and noble canes.

Upon his return to Beltsville, Dr. Price began a cytological study of the canes collected during the 1957 New Guinea expedition.

VARIETIES VARY IN RESPONSE TO NITROGEN

For the purpose of comparing the chemical composition and growth habits of varieties growing in one locality, 10 varieties were chosen by the Genetics Department to be planted at Makiki, in cooperation with the Department of Physiology and Biochemistry. The ground was fumigated with a double dose of methyl bromide to eliminate possible pathogens and to control weeds without the danger of injurious residues of weed killers.

Nitrogen, the only nutrient deficient in this soil, was applied early at two levels, 200 and 400 pounds per acre.

Table 15
Seed Shipments to Plantations
(July 1, 1957 to June 30, 1958)

Source	For Seed Nurseries—Tons	For Grade A Tests—Tons	For 10x20 No. of Plots	For 40x40 No. of Plots
Kailua Field Laboratory	3.65	....	.....	..
Waipio Substation	3.63	....	1,398	25
Hilo Variety Station	.33	....	529	..
Hilo Mauka Var. Sta.	.....	....	29	..
Hamakua Makai Var. Sta.	.....	....	574	1
Hamakua Mauka Var. Sta.	.....	....	79	..
Kohala Variety Station	.70	....	.....	..
Lihue Variety Station	.....	....	28	..
McBryde Variety Station	10.38	2.75	54	9
Totals	18.69	2.75	2,691	35
Total 1956–1957	28.59	....	3,419	61

The varieties planted are 39–3633, 32–8560, H–109, 49–5, 49–104, 37–1933, 38–2915, 39–7028, 44–3098 and 44–2772.

The crop will be one year old on September 28.

Two harvests have been made, at six and nine months of age; the third is set at 12 months.

Already many interesting varietal differences are evident in the different anatomical parts and in their composition.

Juice from millable cane, nine months old, ranges in Brix from a low of 6.06 for H-109 to 14.65 for 49–5. Purities for these two varieties were 57.99 and 86.89, respectively.

Sensitivity to amounts of nitrogen differs strikingly from one variety to another. In some, the Brix and purity are lowered very little by the added 200 pounds of N; in others, they are greatly depressed.

It is especially interesting that the juice qualities at six and nine months of age fall into the same relative positions expected at maturity.

CONTROLLING THE FLOWERING OF CANE

The major means of reducing flowering in sugar cane are: (a) withholding water; (b) treatment with chemicals; and (c) keeping the cane too young to flower either by delaying planting or by cutback. All of these treatments are timed to be effective at initiation time, September 5 to 15.

1. **Withholding water.** All evidence from last year's experiments indicates that, for the average location, August 7 to 10 is the proper time for the last irrigation. Water should be returned to the field as soon as possible after September 15. In a very hot region, or in areas of thin soil, irrigation may be continued until August 18 or 20 and still achieve flower control.

2. **Chemical Sprays.** A number of new chemicals were tested last year for their effect on flowering. None was nearly as effective as CMU, which was again tested for effect of time of application. The later dates had not been previously tried.

Table 16 indicates that CMU, unlike maleic hydrazide and some other chemicals, acts so quickly that application during the initiation period is most effective. On the basis of this information, it is suggested that *application during the second week of September is preferable to that previously recommended*, i.e., August 30 to September 1. The crude (85 per cent) CMU is used as a suspension in minimum gallonage of water.

Table 16

Treatment	Date	% Tassels
5 lbs. CMU/acre	9/3	27
5 lbs. CMU/acre	9/6	12
5 lbs. CMU/acre	9/10	0
5 lbs. CMU/acre	9/13	4
Check		93

3. **Delayed puberty.** By delaying the start of a new crop or by cutting back, cane can be kept too young to initiate flowers in September. There is some evidence that this can also be accomplished by the addition of sufficient nitrogen to keep the cane in a youthful state. (See page 63 of the 1957 Annual Report for the relation between nitrogen and drying off.)

For this experiment, most of the flowering plots were utilized last fall. By ratooning at different times, the age of cane on September 10 was varied from 11 to 23½ weeks. To these plots were applied amounts of nitrogen ranging from 75 to 450 pounds. Twenty tagged stalks in each plot served as the test material, to avoid the apparent effects of nitrogen which come about from increased stands due to high nitrogen.

The results in Table 17 show the marked interaction between age and amounts of nitrogen. Cane ratooned 11 weeks before September 10 (July 1) is too young to flower with any level of nitrogen. Cane 15 weeks old flowers heavily with moderate levels of nitrogen but almost not at all with 300 pounds. Cane 24 weeks old can be largely prevented from flowering by 450 pounds of nitrogen (75 pounds at ratooning + 375 pounds on August 1).

Table 17
% Flowering

Age Weeks	Nitrogen, lbs/A			
	75	150	300	450
11	0	0	0	—
15	64	65	5	—
18	80	96	36	—
23½	—	96	66	19

From the practical point of view, it would seem possible to extend the control of flowering by at least a month, even with a heavy-flowering variety like 37–1933. Fertilizer tests make it clear that in many localities most of the nitrogen can be applied before the cane is five months old without loss in yield. Therefore, if it is planned to use 300 to 400 pounds of N for the crop, much of this can

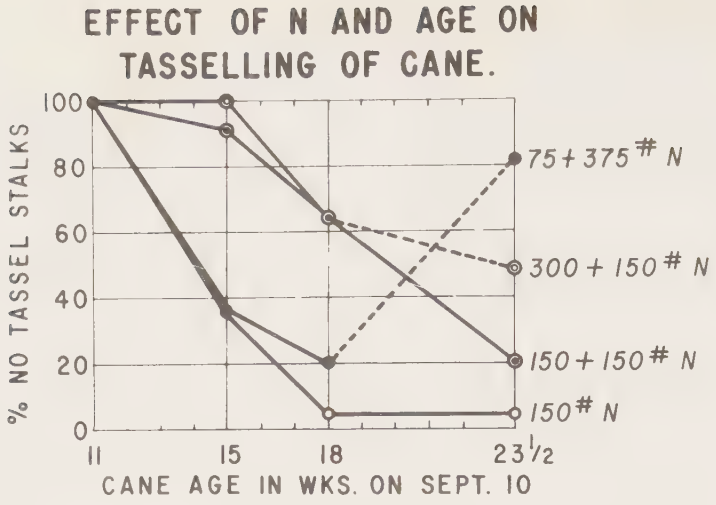

Figure 79.

be applied about the first of August to reduce flowering.

The effect of timing of nitrogen application is well illustrated in Figure 79. A final application on August 1 always reduces the amount of flowering. The two broken lines show the effect of adding 150 pounds on August 1 to cane which had already received 300 pounds; and of adding 375 pounds to cane that had previously received 75 pounds.

PHOSPHATE HAS AN EFFECT ON FLOWERING

During the past three years, it has been observed that sugar cane growing in water culture flowered when there was a marked deficiency in phosphorus. Observations on a pot test being conducted by the Agronomy Department with phosphorus-deficient soils show that tasseling of first ratoon plants of 37–1933 was completely inhibited where raw rock phosphate had been mixed at 800 and 1600 pounds P_2O_5 per acre. Raw rock banded and superphosphate banded and mixed at 800 pounds per acre gave partial or no inhibition. Tasseling occurred in the three highly deficient soils tested with no phosphate added and with super and raw rock phosphate both banded and mixed at 400 pounds per acre.

The most recent of the water culture experiments confirms the favorable effect of low P on flowering.

Plants were grown in three solutions: control, basic minus P, and low N minus P. The only plant to tassel was in the low N minus P series. The stalk of this plant weighed more than the others in that series. This stalk had the lowest percentage of moisture, the highest percentage of sucrose, a low (but not lowest) percentage of reducing sugars, and was, therefore, riper than the other plants. This stalk had the lowest percentage of total P, but was neither the lowest nor the highest in total K or N fractions. Therefore, the ripest stalk, with the lowest P content, flowered.

WEED CONTROL

NEW CHEMICAL HERBICIDES APPEAR FOR SCREENING

2,2-dichloro sodium sulfo ethyl propionate is a new grass killer with properties similar to those of dalapon. It is freely soluble in water, but because of its high acidity the HSPA Inhibitor of Corrosion will undoubtedly have to be added to solutions containing it. Its action on common metals begins on contact. In the case of aluminum, it evolves a continuous generation of hydrogen. It requires the use of a non-ionic wetting agent to avoid chemical antagonism, and it is yet to be determined if its grass-killing properties would be affected were its solutions to be neutralized with an alkali.

Sodium ethyl sulfate of 2,4,5-T is a recently developed compound completely water-soluble at the rate of one-half pound of the 98 per cent chemical in one gallon of solution. It is intended exclusively for pre-emergence use. The manufacturer claims that this compound becomes active only when in contact with the soil. Hence, by implication, he suggests that it cannot have any detrimental effect if accidentally sprayed on vegetation which is sensitive to hormone-type chemicals.

Chloro methyl phenoxy propionic acid is a hormone chemical differing from the conventional 2,4-D in that it has been synthesized by replacing the acetic acid group in the 2,4-D side chain with propionic acid, and the chlorine in the No. 2 ring position with the methyl group. This compound is not soluble in water, but by very simple processing with any one of several amines it may be formulated into a water-soluble stock solution containing ing two and one-half pounds acid equivalent of the chemical per gallon of concentrate.

2,4-dichlorophenoxy acetamide is a new compound marketed as a micronized wettable powder. Since it, like CMU, Simazine, and other compounds of this nature, is insoluble in water, it has to be applied with continuous agitation. However, it may be suspended in water, either permanently or for any desired period, by employing the CPA technique or the ASE-60 latex resin process, which was more recently recommended to plantation users. As suggested by the manufacturer, it is employed exclusively as a pre-emergence application at the rate of two pounds per acre.

Ethyl di-N-propylthiolcarbamate, a new pre-emergence herbicide, is an oily liquid having a purity of 78 per cent. The manufacturer makes some rather outstanding claims for the behavior of this chemical in pre-emergence weed control. For instance, when applied to soil having a moisture content no higher than that needed for the germination of seeds, it is effective in the control of all grasses and many of the broadleaf weeds. It can be made up into a concentrate carrying from four to six pounds of the chemical per gallon and will form a milky-white emulsion when diluted with water for field application. Its action is destructive on weed seeds not only on the surface of the soil, but at a depth of a few inches beneath it. The manufacturer also claims that, at the rate of five to 10 pounds of active material per acre, it will control nut grass. Application should be made within a range of from 20 to 100 gallons of the water-diluted compound per acre, according to the manufacturer.

Further information will appear on all of these new herbicide compounds as formulation and testing data become available.

NEW AROMATIC HERBICIDE OIL UNDER STUDY

Laboratory studies have been made on a new aromatic oil, a sample of which was furnished by Standard Oil Company of California. This new oil, which may replace the 55AR Oil now in use, was manufactured at California Research Corporation, Richmond, California, from crude oils which are to be processed in the Ewa refinery.

The physical and chemical characteristics of this new oil are being studied. It is lighter in density than diesel oil, has a pale straw color, and carries

a mild and non-objectionable odor. When used as a substitute for diesel oil in preparing laboratory batches of Standard CADE, it produced a satisfactory emulsion, the off-white color of which darkened to a light gray upon exposure to the atmosphere. Because of its high aromatic content, it is just possible that it may replace diesel CADE entirely, principally because it should prove more potent as a contact killer.

The new oil carries an as yet undetermined component which, in the presence of OSA, develops a distincly green or bluish-green color. Laboratory studies are continuing in an effort to ascertain the composition of this component and to determine whether this phenomenon might have any bearing, detrimental or advantageous, were this oil to be used in future operations.

A characteristic of this new oil, which is quite unlike that of 55AR Oil, is that it is more difficult to dissolve OSA when the oil has been warmed. However, when OSA is brought into solution with the smallest volume of methanol required, an unusually high concentration of OSA may be impressed on this oil, and the solution will remain stable even after standing several weeks.

OIL-SOLUBLE HSPA ACTIVATOR IN NEW FORM

The oil-soluble Activator (OSA) may now be purchased as an oil-treated product, which eliminates sneeze-provoking dust during processing in the plantation mixing plants. A laboratory study of one particular brand showed that it carried approximately three per cent by weight of a distilled petroleum oil, so that a 100-pound drum will carry 97 pounds of OSA and three pounds of oil. The "oiled" product may be substituted for the dry form in ARCADE Concentrate. However, it should not be used in preparing FAS (Fluid Activator Stock) for the reason that some of the oil which it carries separates in the FAS processing, while the balance forms an unstable emulsion which eventually separates. Another product has been broken up into very small, dry aggregates which are not only dust-free, but which, being non-hygroscopic, are free flowing. It is packed in containers carrying 103 pounds net, so that the user may be assured of obtaining 100 pounds net of the OSA.

Plantation men have been handicapped in processing the oil-soluble activator or in dissolving it in an aromatic oil because heat was required to bring the activator into an oil solution. Furthermore, not all plantations have facilities for doing a job of this kind without risking a fire, or the decomposition of the activator or the oil by overheating. In response to many requests for a method of dissolving the activator in aromatic oil without using heat, a cold-processing procedure is now under study at this Experiment Station. An OSA concentrate which carries seven pounds of the dry chemical and 7.21 pounds of the "oiled" product has been successfully prepared. This concentrate may be added to an aromatic oil to form a perfect solution in a matter of a few minutes. Solutions of the activator and the oil, at various concentrations, may be used in preparing (1) ARCADE Concentrate, (2) a preservative for pani pins, and (3) a new herbicide concentrate for dilution with water to form an unusually good emulsion for contact work.

A new, cold-process, contact herbicide has also been developed. Unlike ARCADE and ARCADE Concentrate, no homogenizer is required in its preparation, and no permanent storage in the mixing plants for APC, OPC, SSA, and FAS will be necessary. The only equipment needed is a "Lightnin" mixer and a mixing tank, or drum. This new concentrate may be varied to suit the requirements of the user by modifying the amount of OSA from 10 to 17½ per cent. It may be prepared from OSA Concentrate No. 1B, or it may be made directly by bringing the OSA into solution in a relatively small quantity of synthetic, anhydrous methanol. From four to six per cent of an emulsifier, made specifically for use with OSA, is added, and the solution is then brought to the required volume with aromatic oil. The concentrate may be diluted to 10 times its original volume for field application by the addition of, or its addition to, water containing from two to four per cent of Standard E50 Solution.

OTHER NEW CHEMICALS HAVE INTERESTING PROPERTIES

Two types of chloro cosanes obtained on the mainland in 1957 are under study. One of them has been found markedly effective in the development of a pani pin preservative when formulated with the new OSA-aromatic oil concentrates. It appears to have a property which causes it to

liberate small but continuous quantities of chlorine from its 70 per cent reserve of this element when it is in contact with wood which is weathering. Indications are that this peculiar property of the chloro cosanes may function to good advantage, both as an insecticide and as a fungicide, for preserving the structure of wood.

The latex resin, known as ASE-60, which was also obtained during the 1957 mainland trip, has been adapted to the suspension in water of micronized, insoluble, wettable powders. Information on this particular development has been forwarded to interested plantation users.

PAINT-LIKE COATINGS AS INHIBITORS OF CORROSION

Corrosion inhibitors for adding to solutions of herbicides, fertilizer concentrates, and fungicides, have been developed at this Experiment Station and are being used on the plantations. These inhibitors arrest corrosion while the solutions containing them are in contact with, and splash about in, mobile metal equipment. However, when such solutions are stored in metal tanks, especially after portions have been drawn off, condensation of moisture will in due course wash off all inhibitor chemicals from the cover and tank sides above the liquid level. As a consequence, corrosion will set in above this point and becomes progressively intense as moisture condenses at night and drains down to the liquid level the following day.

Hard-setting, paint-like coatings have been used for years in efforts to overcome condensation corrosion. Very few of these paints have been satisfactory, however, because many of them leave pinhole voids which allow the corrosive solution to seep through and spread between the coating and the bare metal. Another failing of hard-setting coatings is that their coefficient of expansion and contraction is seldom the same as that of the metals they cover, resulting eventually in their breaking loose and scaling off.

Experiments have been made with a product of a large Eastern oil company. Termed a "fluid film", this material is incorporated with a soft, paint-like coating which never sets hard and which is applied by brush or spray to the entire inner and outer surfaces of the metal container. The manufacturer claims that it is neither necessary nor desirable to remove any rust except loose particles since the film penetrates the imbedded rust to the bare metal and remains there as a protective cover. This fluid film gradually stiffens to a flexible membrane. In tests with the product, it appears to be impervious to water and to chemical action by many fertilizer solutions.

FIELD SCREENING OF NEW HERBICIDES

The newer herbicides tested during the last year have included oil-soluble Triazine (G 30031) in comparison with Simazine, Simazine in CADE, in ARCADE and in water and trichlorobenzoic acid and trichlorobutyric acid in comparison with 2,4-D, 2,4,5-T, and Silvex. Studies with Silvex have reached the point where samples of sugar cane are being analyzed for effects of this compound on sugar cane in anticipation of its registration for use in the industry.

Simazine has proved in many tests to be as effective for pre-emergence control of weeds as CMU or DCMU, and in some cases it is superior to CMU. Simazine has been applied satisfactorily in water and in diluted CADE or ARCADE. Tests with radioactively-tagged Simazine are under way as a prelude to the registration of this herbicide for use in sugar cane. The oil-soluble form of Triazine (G 30031) has, in a few tests, proved as effective as Simazine on a pound-for-pound basis.

Trichlorobenzoic acid has proved effective as a pre-emergence herbicide, but in several tests it has had damaging effects on sugar cane. Trichlorobutyric acid has not proved satisfactory for use in sugar cane.

SOIL FUMIGANTS AS HERBICIDES

Studies with soil fumigants have included methyl bromide as a gas, methyl bromide with diesel oil, ONCB and Vapam.

ONCB and Vapam have shown value as herbicides when applied at 400 pounds per acre. Incorporation of the chemicals in the soil by rototilling is necessary for most efficient results.

Methyl bromide has continued to prove valuable as a herbicide when applied under a gas-tight cover (Figure 80). Levels of application from one-half to one and one-half pounds per 100 square feet have proved effective. Tractor injection of methyl bromide in diesel oil followed by a gas-tight cover has shown promise. This study is being

Figure 80. In an area heavily infested with nut grass, methyl bromide was released under a polyethylene cover at the rate of 1.5 pounds per 100 square feet of ground. The fumigation not only destroyed the nut grass completely, but destroyed seeds of other weeds as well. Only a few plants of crotalaria emerged.

made cooperatively by the Agronomy and Pathology Departments.

In a heavy clay soil, methyl bromide, at one and one-half pounds per 100 square feet, completely destroyed a heavy infestation of nut grass. Similar treatments on sandy soils have not been successful in destroying nut grass because the gas has diffused too rapidly in the sand.

HERBICIDAL EFFECTS ON SUGAR CANE

Numerous studies have been conducted during the year to determine effects of the different herbicides on sugar cane. Tests on plantations have shown the following results:

1. Of the three herbicides, CMU, DCMU and Simazine, CMU is the most damaging to sugar cane. The other two compounds at higher levels of application may cause chlorosis and reduced growth, symptoms similar to those caused by CMU.

2. Factors that influenced damage from CMU and, it is believed, also from DCMU and Simazine, were level of organic matter in the soil and, at least partially, pH. Tillering was likewise reduced. In one soil where the phosphate level was critically low, CMU caused severe damage to the phosphate-deficient sugar-cane plants. In this case, three and one-half pounds of CMU per half-acre foot killed the crop plants, whereas in soils that were not deficient in phosphate, much less severe effects were observed.

3. The various forms of 2,4-D and dalapon caused severe damage to germinating sugar cane (Figure 81). CMU and Simazine applied directly to the sugar-cane seedpieces did not reduce germination.

4. Dalapon on sugar cane may produce "tangle top" symptoms due to inhibited or reduced growth of the main spindle and the terminal shoot. Chlorotic blotching accompanies this condition. Reduced stalk size and tillering result from heavy applications. Light applications may result in increased tillering after reduction in growth of the primary terminal shoot.

5. Symptoms of drought may at times be mistaken for those of herbicide damage. "Tangle top" symptoms resembling those caused by dalapon may result from stunting due to drought. Symptoms of curvature resembling those caused by 2,4-D have accompanied heavy winds during win-

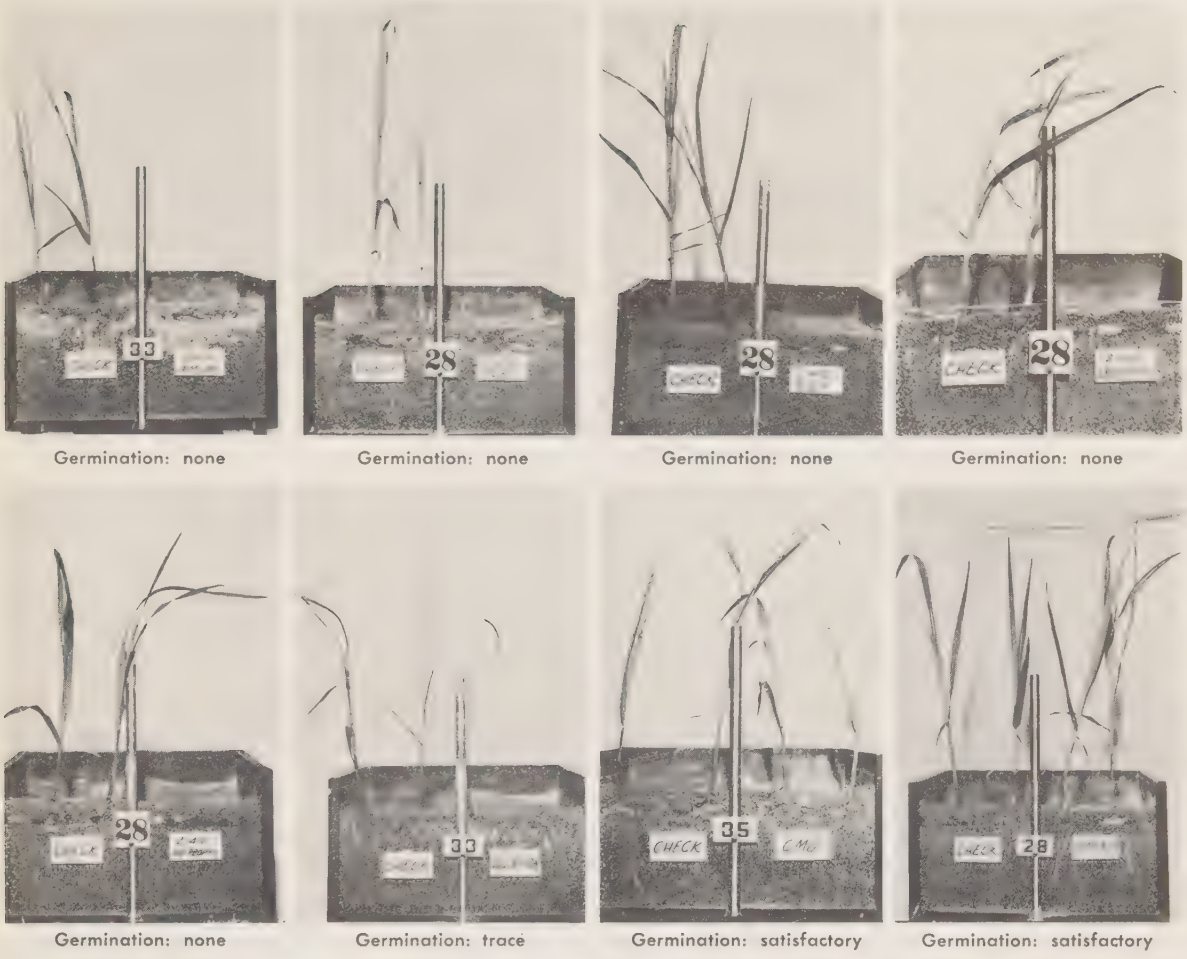

Figure 81. The effect of herbicides on sugar-cane seedpieces was studied in cooperation with Ewa Plantation. Seedpieces of Variety 37-1933 were dipped in solutions of eight herbicides at concentrations of five pounds active ingredient per 50 gallons of mix, and were then planted in vermiculite. The placard on each treatment gives the age in days of the test at the time it was photographed. Results show that the translocated (growth regulator) type of herbicide cannot be sprayed on uncovered seedpieces without affecting germination.

ter periods when sugar-cane stalks are weak and may bend readily. Phototropic response may cause stem curvature that may be mistaken for effects of 2,4-D in this case.

MECHANICAL HERBICIDE APPLICATOR DESIGNED

In exploring the possibilities of economy in weed control, a spray unit which would have desirable features for broadcast and interline spray, and also have potential for spot spray was investigated by Station engineers. The original idea was a minimum unit as to size, power, traction, and cost. As design progressed, the more logical starting point appeared to be a less limited unit. One factor being explored is the potential of a unit with low-pressure tires in furrow-irrigated cane. The minimum type of unit could be a second phase of this work.

The unit being fabricated is described by the following specifications:

1. Gauge 66 inches, wheel base 84 inches.
2. Weight: empty 4300 pounds, loaded 5500 pounds.

3. Four Terra-tires, herringbone tread, 36 inches in diameter by 20 inches wide, with a 10-inch bead.

4. Ground pressure, 4 to 6 psi.

5. Jeep engine, transmission, and final drives. Four-wheel drive.

6. Travel speeds, one to 11 mph.

7. Power steering, foot or hand control.

8. Spray pattern, broadcast six lines, interline four lines, spot two lines.

9. Tank capacity, 150 gallons.

10. Over-all width reducible to nine feet for highway travel.

11. Solenoid controlled spot spray valves.

OTHER DEVELOPMENTS ON HERBICIDE APPLICATION EQUIPMENT

1. Improved spray nozzles for CMU have been obtained from the Spraying Systems Company.

2. Point injection of methyl bromide has been devised for spot treatment (Figure 82).

3. A single-tank knapsack utilizing the F-1 (1000 cubic inch) oxygen tank has been constructed.

4. A boom skid for interrow spraying was tested on a high-and-wide TD-9 tractor at Pepeekeo (Figure 83). This skid proved very satisfactory for interline spraying with a minimum of damage to the crop plants.

Figure 82. Point injector for methyl bromide for individual plant or spot treatments. The burner in the foreground detects methyl bromide fumes.

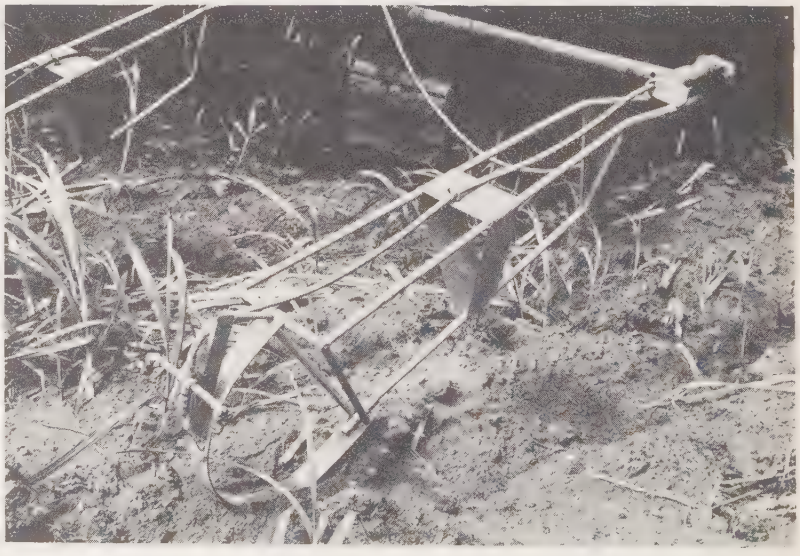

Figure 83. Boom skid adjusts spray height on Pepeekeo's TD-9 high-and-wide spray tractor. A short three-nozzle boom, with off-center spray fans on the outside and a 95° spray fan in the center, covers the interline at a uniform height. In this way, the spray is kept so low that it does not affect the cane leaves. Repeated sprayings of 2,4-D, TCA and Dalapon, have been made without injury to the crop plants.

TRAINING OF PERSONNEL

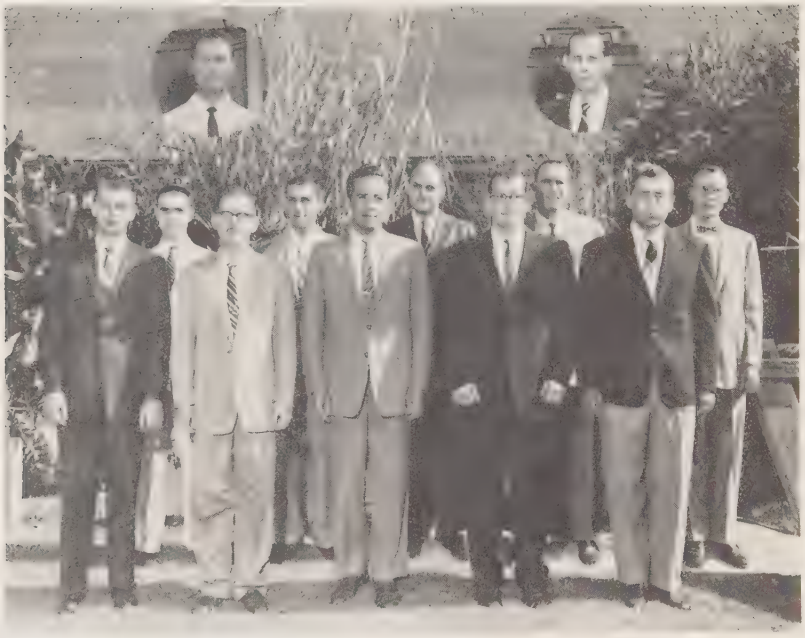

Figure 84. Assistants-in-Training for Agriculture: Robert D. Wiemer, W. Garvie Hall, S. Russell F. Sowers, James W. Smith, Jr., Karl Pfenninger, Robert S. Sutherland, Lindsay A. Faye, Jr., James W. Ednie, John C. Meldeen, Don P. Scott. Inserts: Morton S. Rothberg and George C. Schattenburg.

Figure 85. Assistant-in-Training for Sugar Technology: Arthur L. Flores.

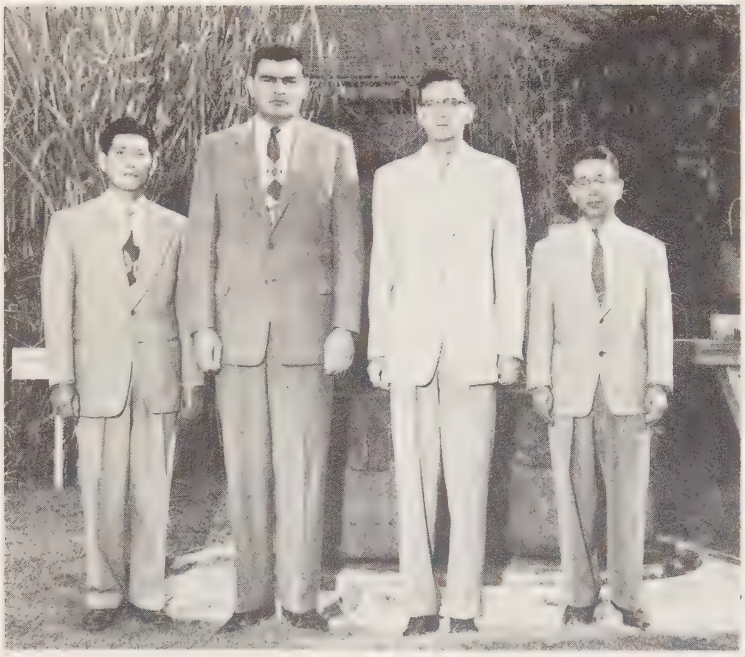

Figure 86. Plantation Enrollees for Short Course in Agriculture: Jose A. Bumanglag, Robert S. Anderson, Daniel J. Dougherty, James T. Nagasako.

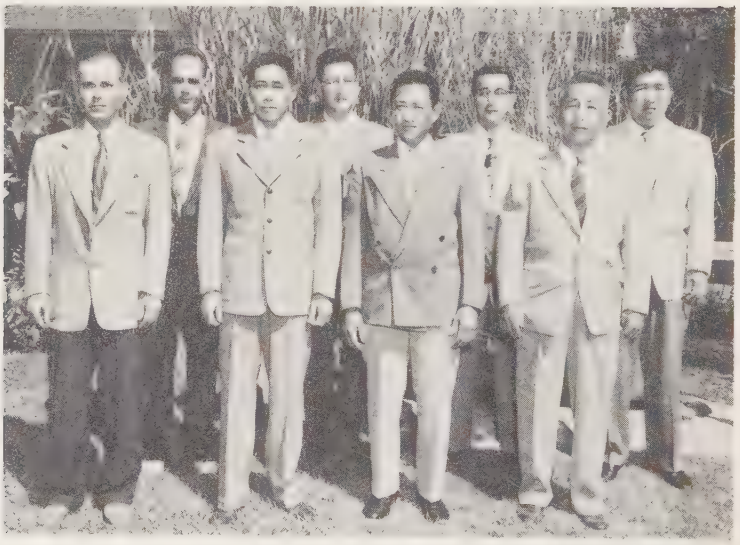

Figure 87. Plantation Enrollees for Short Course in Factory Technology: Jack Sasaki, Lionel Andrade, Waichi Hiraoka, Thomas Takiguchi, Solomon Lee, Yoshio Murai, Yutaka Masaki, and Toshio Shirasaki.

EXPERIMENT STATION STAFF

September 30, 1958

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L. Nakatsuka ..... *Senior Substation Assistant*

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Kauai

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Richard Boyen ..... *Executive Secretary*
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G. E. Lambert ..... *Instrument Technical Assistant*

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W. P. Burton ..... *Project Engineer*
W. E. Hart ..... *Project Engineer*
C. B. Holtwick ..... *Project Engineer*
W. H. Kahl ..... *Project Engineer*
E. P. Morgan ..... *Project Engineer*
W. W. Sewell ..... *Project Engineer*
T. Adachi ..... *Design Engineer*
S. Kawamura ..... *Design Engineer*
S. Matsuoka ..... *Design Engineer*
E. M. Norum ..... *Assistant Project Engineer*
G. S. Palmerton ..... *Assistant Design Engineer*
T. R. Uyechi ..... *Assistant Design Engineer*
J. M. Feiteira, Jr. ..... *Design Draftsman*
J. H. S. Kim, Jr. ..... *Design Draftsman*
Y. Isa ..... *Shop Foreman*

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Sam Price ..... *Associate Geneticist (Coop. USDA)*
R. Urata ..... *Associate Geneticist*
D. W. Davis ..... *Assistant Geneticist*
A. Doi ..... *Assistant Geneticist*
H. Terayama ..... *Administrative Assistant*
R. Chi ..... *Senior Genetics Assistant*
N. Kimura ..... *Senior Genetics Assistant*
M. Tanaka ..... *Field Laboratory Superintendent*

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Jen-Hu Chang ..... *Assistant Geophysicist*
T. Hayashi ..... *Senior Laboratory Assistan*

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T. Yamamoto ..... *Assistant Organic Chemist*

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C. A. Wismer ..... *Senior Pathologist*
H. Koike ..... *Associate Pathologist*

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H. W. Brodie ..... *Senior Physiologist*
Constance E. Hartt ..... *Associate Physiologist*
H. P. Kortschak ..... *Associate Biochemist*
T. Tanimoto ..... *Associate Biochemist*
G. J. Davis ..... *Assistant Physiologist (Coop. USDA)*
Ada Forbes ..... *Assistant Physiologist*
David Takahashi ..... *Assistant Biochemist*
H. Agena ..... *Senior Laboratory Assistant*

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G. E. Sloane ..... *Senior Technologist*
Chen-Chuan Tu ..... *Senior Technologist*
R. K. Hamilton ..... *Associate Technologist*
Toshio Moritsugu ..... *Associate Technologist*
L. J. Rhodes ..... *Associate Technologist*
G. F. B. Appel, Jr. ..... *Assistant Technologist*
F. J. Dupin ..... *Scale Inspector*
K. M. Onna ..... *Assistant Technologist*
H. S. Iwata ..... *Technical Assistant*

TRAINING OF PERSONNEL

W. P. Alexander ..... *Principal Coordinator*

STATION PERSONNEL CHANGES

JOINED THE STAFF

R. B. Arakaki	*Senior Assistant*	Industrial Engineering
Jen-Hu Chang	*Assistant Geophysicist*	Geophysics
D. W. Davis	*Assistant Geneticist*	Genetics
J. M. Feiteira, Jr.	*Design Draftsman*	Field Engineering
Warren Gibson	*Principal Industrial Engineer*	Industrial Engineering
W. H. Narahara	*Technical Assistant*	Agronomy
F. E. Robinson	*Associate Agronomist*	Agronomy
W. R. Smythe	*Assistant Entomologist*	Entomology

LEFT THE STAFF

A. H. Cornelison	*Associate Agronomist*	Agronomy